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Afognak Lake Sockeye Salmon Stock Monitoring, 2014

by

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and

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May 2015

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

Concerns expressed by local subsistence users over declines in Afognak Lake sockeye salmon *Oncorhynchus nerka* prompted the Alaska Department of Fish and Game to investigate Afognak Lake's rearing environment. Funded through the U.S. Fish and Wildlife Service Office of Subsistence Management and Alaska Sustainable Salmon Fund, this report provides results from the 2014 season.

Based on established mark-recapture techniques, an estimated 218,239 sockeye salmon smolt outmigrated from Afognak Lake in 2014. From 2010 to 2014, the outmigration averaged 258,043 and ranged from 127,862 to 329,948. Age-1 smolt comprised 62% of the outmigration in 2014 and averaged 80% of the outmigration from 2009 to 2013. Although age, weight, and condition data indicate healthy, robust smolt, a life-history based model produced a significantly larger estimate, which could indicate poor survival prior to the outmigration.

Exploratory stomach content analysis from juvenile coho salmon inhabiting the lake shoals revealed evidence of predation upon juvenile sockeye salmon.

Limnological sampling was conducted during 5 monthly events from May to September in 2014. Phosphorus concentrations and zooplankton densities remained low, while chlorophyll-*a* levels maintained average values throughout the study. Nitrogen concentrations, lake temperatures, and phytoplankton biovolume rose for the third consecutive year. Notably, the 2014 phytoplankton biovolume reached approximately 300 times that of 2012 and 500 times that of 2011.

Afognak Lake sockeye salmon returned in sufficient numbers to meet the escapement goal and support subsistence, sport, and commercial harvests. Escapement was 36,345 fish in 2014, averaging 44,300 sockeye salmon and predominately composed of age-1.3 and age-1.2 fish (2010–2014).

Key words: Afognak Lake, Litnik, mark-recapture, age, outmigration, escapement, bioenergetics, Kodiak Island, *Oncorhynchus nerka*, smolt, sockeye salmon, subsistence harvest, inclined-plane trap, zooplankton

INTRODUCTION

The Afognak Lake (also referred to as "Litnik" by local residents) watershed is located on the southeast side of Afognak Island, approximately 45 km northwest of the city of Kodiak (Figure 1). Afognak Lake (58°07′ N, 152°55′ W) lies 21.0 m above sea level, is 8.8 km long, has a maximum width of 0.8 km, and has a surface area of 5.3 km^2 (Schrof et al. 2000; White et al. 1990). The lake has a mean depth of 8.6 m, a maximum depth of 23.0 m, a total volume of 46.0×10^6 m^3, and an estimated lake-water residence time of 0.4 years (Figure 2). Afognak Lake drains in an easterly direction into the 3.2 km long Afognak River, which in turn flows into Afognak Bay. Afognak Bay is part of the Alaska Maritime National Wildlife Refuge and is where most localized subsistence salmon fishing occurs. The Afognak Native Corporation owns the land surrounding the Afognak Lake watershed down to tidewater.

A counting weir for adult salmon was first established on Afognak River in 1921 just below the lake outlet and was operated intermittently through 1977. From 1978 to the present, the weir has been consistently operated. In 1986, the weir was relocated to its current location, approximately 200 meters upstream of the Afognak River mouth. The Alaska Department of Fish and Game (ADF&G) has conducted annual weir counts in conjunction with sockeye salmon *Oncorhynchus nerka* age, sex, and length (ASL) sampling at the current site. Catch data have been documented through the ADF&G commercial landing fish ticket system, statewide sport fish surveys, and subsistence fishing permits since the late 1970s (Jackson et. al 2014).

In response to declining adult returns, in 1987, ADF&G, in cooperation with the Kodiak Regional Aquaculture Association (KRAA), initiated pre-fertilization fisheries and limnological investigations at Afognak Lake (Honnold and Schrof 2001; Schrof et al. 2000; White et al. 1990). Results of these investigations indicated that sockeye salmon production was limited by rearing capacity (White et al. 1990). Nutrient enrichment was recommended and implemented in 1990 to increase primary and secondary production with the intention to increase sockeye salmon rearing capacity in the lake. ADF&G and KRAA fertilized Afognak Lake for 11 years (1990–2000).

Afognak Lake sockeye salmon runs substantially declined beginning in 2001, and escapements from 2002 through 2005 were below the established sustainable escapement goal (SEG) range of 40,000 to 60,000 sockeye salmon (Baer 2011; Honnold et al. 2007; Jackson et al. 2014; Nemeth et al. 2010). As a result of these poor runs, the commercial sockeye salmon fishery in the Southeast Afognak Section (Figure 1), which includes all of Afognak Bay and surrounding waters, was closed from 2001 until 2005 and again in 2007.

In 2004, new sustainable salmon management policies, 5 ACC 39.222 and 5 ACC 39.223, provided the framework to a team of ADF&G biologists to re-evaluate the existing Afognak Lake sockeye salmon escapement goal. The team recommended changing the escapement goal from an SEG of 40,000 to 60,000 sockeye salmon to a biological escapement goal (BEG) of 20,000 to 50,000 sockeye salmon (Nelson et al. 2005). The recommendation was based on analysis of a Ricker spawner-recruit model and limnology data, excluding data from years in which the lake was fertilized. In 2007 and 2010, the escapement goal was re-evaluated with additional years of data and was recommended to remain unchanged (Honnold et al. 2007; Nemeth et al. 2010).

Escapements during the last decade have been just below (2002 and 2004) to just above (2001, 2003, 2005–2008) the lower bound of the BEG (Appendix A13). The Afognak River sockeye salmon run has only recently (2010–2013) regained sufficient numbers to meet the escapement goal (20,000–50,000) and support commercial harvest.

In addition to sockeye salmon, other fish species in the Afognak Lake drainage include pink salmon *O. gorbuscha*, coho salmon *O. kisutch*, rainbow trout (anadromous and potamodromous) *O. mykiss*, Dolly Varden *Salvelinus malma*, threespine stickleback *Gasterosteus aculeatus*, and coastrange sculpin *Cottus aleuticus* (White et al. 1990). Chinook *O. tshawytscha* and chum *O. keta* salmon have been observed in the Afognak River on occasion but have not established discernible spawning populations (White et. al 1990).

Afognak Lake sockeye salmon are an important target species for salmon fisheries within the Kodiak region. Residents of Port Lions, Ouzinkie, Afognak Village, and Kodiak have traditionally harvested salmon in Afognak Bay for subsistence uses (Figure 1). Local subsistence users, represented by the Kodiak-Aleutians Regional Advisory Council, Kodiak Fish and Game Advisory Committee, and Kodiak Tribal Council, contended that continued closures of the Afognak system would make it more difficult for local residents to harvest sockeye salmon and would shift fishing effort to small nearby sockeye salmon runs and the Buskin River, constituting an emergency situation. In response to this situation, ADF&G received funding through the Office of Subsistence Management's (OSM) Fishery Resources Monitoring Program to determine the feasibility of estimating sockeye salmon smolt production coming out of Afognak Lake. The 2003 study showed that sockeye salmon smolt could be effectively trapped in Afognak River and their abundance reliably estimated using mark–recapture techniques (Honnold and Schrof 2004).

Continued analysis of Afognak Lake sockeye salmon returns and annual smolt outmigration studies were deemed of high importance for assessing the growth and production of juvenile sockeye salmon. Recognizing the importance of continued studies on Afognak Lake sockeye salmon production, OSM approved project funding from 2014 to 2017 to ADF&G for smolt and limnological studies, and the Alaska Sustainable Salmon Fund (AKSSF) approved funding for adult enumeration from 2014 to 2015.

The goal of this project was to obtain reliable estimates of smolt and adult production over time for Afognak Lake. Data collected from this project have enabled researchers to better identify factors specifically affecting and controlling sockeye salmon production within the freshwater environment. This information continues to help refine the escapement goal and improve pre-season run forecasts to allow for maximum sustainable yield and prevent unnecessary restrictions of federal and state subsistence fisheries.

This report summarizes the 2014 data collected and evaluates sockeye salmon production at Afognak Lake.

PROJECT OBJECTIVES

Smolt

1. Estimate the abundance (*N*), age composition, and average size of outmigrating sockeye salmon smolt within 25% (relative error) of the true value with 95% confidence.
2. Estimate the abundance of outmigrating sockeye salmon smolt using a life-history based model for a comparison estimate with the mark–recapture techniques.
3. Estimate the age composition of outmigrating sockeye salmon smolt within d=0.05 (size of the effect) of the true proportion (for each major age group within each stratum) with 95% confidence.
4. Estimate the average length (mm), weight (g), and condition (Fulton's condition factor K) by smolt age group and stratum.

Adult salmon

5. Enumerate the escapement of adult sockeye salmon returns through the weir and into Afognak Lake.
6. Estimate the age and sex composition of adult sockeye salmon returns where estimates are within d=0.07 of the true proportion (for each age group within each statistical week) with 95% confidence.
7. Estimate the average length (mm) of adult sockeye salmon by age and sex.

METHODS

SMOLT ASSESSMENT

Trap Deployment and Assembly

Two inclined-plane traps (Ginetz 1977; Todd 1994) were placed in Afognak River on May 7 to capture outmigrating smolt in 2014. The downstream trap was installed approximately 32 m upstream from the adult salmon weir site and was utilized for smolt enumeration and the recapture of marked fish (Figure 3). The upstream trap was installed approximately 1.2 km upstream from the adult salmon weir site and was utilized solely to capture smolt for dye release testing.

Prior to 2012, a single inclined-plane trap was utilized to capture outmigrating smolt. The single-trap system required transportation of smolt from the capture site to the release site, creating unnecessary smolt mortality. Switching to a 2-trap system reduced smolt mortality and will continue as the preferred method.

Both traps were positioned in the thalweg of the river at each location, where water velocity was great enough to reduce trap avoidance and capture a representative portion of the outmigrating smolt. A live box (1.2 m x 1.2 m x 0.5 m) was attached to the outlet of each trap, and both trapping devices were connected to cables attached to hand-powered cable "come-along" winches fixed to each stream bank. Both traps were secured to an aluminum pipe frame, which allowed the back end of the trap and live box to be adjusted vertically in response to water level fluctuations.

Smolt trapping operations were concluded when daily smolt counts were less than 100 smolt per day for 3 consecutive days. Detailed methods of trap installation, operation, and maintenance are described in the 2014 Afognak Lake Operational Plan (Thomsen and Estrada 2014).

Smolt Capture and Handling

Smolt trap live boxes were checked every 1 to 2 hours during the night (2200 to 0800 hours), depending on smolt abundance. During the day (0801 to 2159 hours), the live boxes were checked every 3 to 4 hours. All smolt were removed from the live boxes with a dip net, counted, and either released downstream of the trap or transferred to an instream holding box for sampling or marking. The lower trap fished continually and the upper trap was only fished until the required numbers of smolt were captured for the upcoming mark-recapture (dye release) test. Species identification was made by visual examination of external characteristics of juvenile salmonids (Pollard et al. 1997). All data, including mortality counts, were entered on a reporting form each time the trap was checked.

Trap Efficiency and Mark–Recapture Abundance Estimation

Total smolt abundance was estimated using mark–recapture procedures to estimate trap efficiency within each specific recapture period (weekly strata). Trap efficiency was then used to estimate the number of smolt outmigrating from the watershed during each stratum.

Releases of sockeye salmon smolt marked with Bismarck Brown Y dye were made once per strata (weekly), as well as when changes were made to the trapping system. As in previous years at Afognak Lake, an effort was made to achieve trap efficiencies from 15% to 20% (Thomsen and Richardson 2013). To estimate total smolt abundance for each strata with a 5% probability of exceeding a relative error (RE) of 25%, a minimum of 330 smolt were marked and released for each experiment (Carlson et al. 1998). To estimate mortality associated with the marking, holding, and transport process, 50 marked and 50 unmarked fish were retained and monitored for 4 days after the release of dyed fish. Therefore, a sample size of 650 was targeted as the goal for each experiment to account for mortality and testing. Actual numbers of fish marked, released, and retained for mortality testing varied by release event (Tables 1 and 2).

Dyeing Procedure

Smolt captured for dye release testing at the downstream trap required treatment prior to transportation to the release site (steps 1-2). The marking of smolt captured at the upstream trap required no transportation and followed Steps 3–5. If transported, smolt were hauled in a trailer pulled by an all-terrain vehicle to the release site approximately 1.7 km upstream.

1. Collected smolt were placed in a 26-gallon lidded cooler filled with river water and a 0.25% sodium bicarbonate solution to maintain a stable pH. Non-iodized salt was added to the transport water to achieve a 0.75% solution to replicate physiological levels and reduce metabolic stress and electrolyte depletion that can cause post-transport mortality. The transport cooler was continuously supplied with supplemental oxygen at a level of 9 mg/L and within an 80–100% saturation range to maintain conditions similar to ambient river water from which the smolt were collected.
2. Following transport to the release site, smolt were continuously supplied with supplemental oxygen and held for 30 minutes to minimize stress before the dyeing process.
3. Collected smolt were placed into a 26-gallon covered cooler. Prior to adding the dye, 50 smolt (undyed) were randomly selected and placed in a separate holding box for 4 days to estimate holding mortality. The 26-gallon cooler was filled with river water and a 0.25% sodium bicarbonate and Bismarck Brown Y dye (30 mg/L) solution. The smolt were continuously oxygenated and submerged in the solution for 30 minutes. Dyed smolt that displayed unusual behavior (labored respiration, flared gills, side swimming, etc.) were removed from the experiment and released downstream of the recapture site.
4. Approximately 50 dyed smolt were randomly selected, enumerated, and left in a separate holding box for 4 days to estimate delayed mortality resulting from the capture and marking process. The proportion of smolt (dyed minus undyed) that died during the 4-day holding period was used to estimate the actual number of marked smolt available for recapture in the experiment (M_h). M_h was adjusted by multiplying the delayed mortality ratio (total number of marked and held divided by total number of marked dead) by the number of dyed smolt released.
5. The dye solution was replaced with river water and the smolt were held for 30 minutes before release. The remaining dyed smolt (roughly 550) were placed in 5-gallon buckets for release. Timing of the dyeing process was started so dyed smolt were released across the width of the stream between 2100 and 2300 hours.

All dyed smolt recaptured at the downstream trap site were counted and assigned to the strata corresponding to the time period starting the day of their release until the day before the next release and mark-recapture event.

Statistical Formulas

Trap efficiency (E_h) for stratum *h* was calculated as

$$E_h = \frac{m_h + 1}{M_h + 1}, \tag{1}$$

where

M_h = number of marked smolt released in stratum *h*

(Note: M_h is adjusted for marking and holding mortality)

m_h = number of marked smolt recaptured in stratum *h*.

A modification of the stratified Petersen estimator (Carlson et al. 1998) was used to estimate the number of unmarked smolt N_h emigrating within each stratum h as

$$\hat{N}_h = \frac{(n_h+1)(M_h+1)}{m_h+1}, \tag{2}$$

where

n_h = number of unmarked smolt recaptured in stratum h.

Variance of the smolt abundance estimate was estimated as

$$v\left(\hat{N}_h\right) = \frac{(M_h+1)(n_h+1)(M_h-m_h)(n_h-m_h)}{(m_h+1)^2(m_h+2)}. \tag{3}$$

Total abundance of N of unmarked smolt over all strata was estimated by

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h, \tag{4}$$

where L is the number of strata. Variance for $\hat{N}$ was estimated by

$$v\left(\hat{N}\right) = \sum_{h=1}^{L} v\left(\hat{N}_h\right), \tag{5}$$

and 95% confidence intervals were estimated using

$$\hat{N} \pm 1.96\sqrt{v\left(\hat{N}\right)}, \tag{6}$$

which assumes that N is approximately normally distributed.

Within each stratum h, the total population size by age class j was estimated as,

$$\hat{N}_{jh} = \hat{N}_h \, \hat{\theta}_{jh}, \tag{7}$$

where $\hat{\theta}_{jh}$ is the observed proportion of age class j in stratum h. Variance of $\hat{\theta}_{jh}$ was estimated using the standard variance estimate of a population proportion (Thompson 1987). The variance of $\hat{N}_{jh}$ was then estimated by

$$v\left(\hat{N}_{jh}\right) = \hat{N}_h^2 \, v\left(\hat{\theta}_{jh}\right) + \hat{N}_h \, v\left(\hat{\theta}_{jh}\right)^2. \tag{8}$$

The total number of emigrating smolt within each age class was estimated by summing the individual strata estimates, and its variance was likewise estimated by summation over the individual strata estimates.

Statistical Assumptions

Statistical smolt assumptions were taken from Carlson et al. (1998):

- the smolt population was unchanging (i.e., a closed population with no immigration or outmigration),
- all smolt had the same probability of being marked (i.e., trap is not selective and strata are consistent),
- all smolt had the same probability of capture (i.e., marking fish does not affect their behavior or ability to be captured),
- all marked smolt released can be recovered (i.e., marking mortality was accurate),
- all marked smolt were identifiable (i.e., crew well trained and strata are discrete),
- marks were not lost after marking (i.e., effectively dyed for external verification),
- all adult females will successfully spawn, and
- all adult males can fertilize eggs from more than one female.

Life History-Based Abundance Estimation

In addition to a mark–recapture abundance estimate, the estimated number of smolt, by brood year, expected to emigrate in 2014 was calculated using a life history-based approach (Table 3). This approach applied fecundity information estimates to the brood year (2011 & 2012) female escapement to estimate egg deposition. The egg deposition estimate was then reduced using estimates of egg-fry survival and fry-smolt survival to estimate the total number of smolt expected to emigrate for each brood year (Table 3; Figure 8).

Age, Weight, and Length Sampling

To ensure proportional abundance sampling, approximately 2% of the daily sockeye salmon smolt catch was sampled to obtain age, weight, and length (AWL) data. For every 100 sockeye salmon smolt counted out of the trap, the field crew retained 2 smolt for AWL sampling the following morning. Sampling days occurred for a 24-hour period from noon to noon and were identified by the date of the first noon-to-midnight period. Traps were checked more frequently throughout the evening during periods of increased smolt outmigration. Smolt were collected throughout the night and held in an instream live box. The following day, all smolt in the live box were anesthetized using tricaine methanesulfonate (MS-222) prior to being sampled. After being sampled, all smolt were held in aerated buckets of river water until they recovered from the anesthetic and subsequently released downstream from the trap.

Scales were removed from the preferred area of each fish following procedures outlined by the International North Pacific Fisheries Commission (INPFC 1963) and mounted on a microscope slide for age determination. Age was estimated from scales viewed with a microfiche reader at 60X magnification and recorded in European notation (Koo 1962) following the criteria established by Mosher (1968). Fork length (L) was recorded to the nearest 1 mm and weight (W) to the nearest 0.1 g. In addition, the overall health or condition factor of each sampled smolt was assessed by calculating its body condition factor (*K*; Bagenal and Tesch 1978) as

$$K = \frac{W}{L^3} 10^5 \quad . \tag{9}$$

ADULT SALMON ASSESSMENT

Weir Installation and Adult Salmon Enumeration

A 27 m long weir was installed perpendicular to the stream flow and consisted of 10 wooden tripods (each tripod consisting of three 4″ x 4″ x 8′ spruce timbers and 2″ x 6″ x 6′ horizontal cat-walk supports), 33 aluminum pipes (2″ x 10′), 44 picketed aluminum panels (1″ aluminum pipe with 1″ spacing totaling 30″ x 6′), and 2 framed panel gates (Figure 4). All materials were secured with large rocks and zip-ties to create a fish-tight structure that conformed to the contour of the stream channel.

Two counting gates were placed between panels in the 2 deepest channels of the river enabling fish to be counted as they passed through the weir. A white flash panel was placed on the substrate beneath each gate to enhance visibility and species identification. Fish were counted by field technicians using hand tally denominators as fish migrated upstream through the gates. The counting gates remained closed until staff were present to count fish through the weir for escapement enumeration or when fish were being collected into the live trap for age, sex, and length sampling (ASL; Thomsen and Estrada 2014).

Age, Sex, and Length Sampling

An upstream "Scott live trap" (local name for a modified trap capable of capturing steelhead; Figure 4) was installed in front of the east bank gate, which acted as a sampling trap as well as a downstream steelhead trap. The trap consisted of 6 weir panels placed horizontally in the river in the form of a diamond (Thomsen and Estrada 2014).

Escaping adult sockeye salmon were sampled at the weir site throughout the run. Details and procedures for adult sampling are outlined in the *Kodiak Management Area Sockeye Salmon Catch and Escapement Sampling Operational Plan, 2015* (Wattum 2015). All scales, when possible, were collected from the preferred area of each fish (INPFC 1963). Scales were mounted on scale "gum" cards and returned to the Kodiak ADF&G office where impressions were made on cellulose acetate (Clutter and Whitesel 1956). Fish ages were determined by examining scale impressions for annual growth increments using a microfiche reader fitted with a 60X lens following designation criteria established by Mosher (1968). Ages were recorded using European notation (Koo 1962), where a decimal separates the number of winters spent in fresh water (after emergence) from the number of winters spent in salt water (e.g., 2.3). The total age of the fish includes an additional year representing the time between egg deposition and emergence of fry. Length measurements were taken from mid eye to tail fork to the nearest 1 mm, and sex was determined from external morphological characteristics.

Age and sex composition of the upstream migrating adult sockeye salmon were estimated as a group of proportions (p_{ij}) characterizing a multinomial distribution:

$$\hat{p}_{ij} = n_{ij} / n, \tag{10}$$

where

n = number in the sample

n_{ij} = number in the sample of age i and sex j.

On days where escapement occurred but no samples were collected, proportions were estimated by linear interpolation between sampling events. The sample size was selected so that the proportion of each major age group (by statistical week) was estimated within at least α=0.07 of its true value 95% of the time (Thompson 1987). Standard error of the age proportions was calculated as the square root of estimated variance of a proportion (Thompson 1987).

LIMNOLOGICAL ASSESSMENT

Lake Sampling Protocol

Five limnological surveys of Afognak Lake were conducted at approximately 4-week intervals from May to September, 2014. Two stations, marked with anchored mooring buoys and located with Global Positioning System equipment, were sampled from a float plane during each survey (Figure 2). Zooplankton samples were collected at both stations, but water samples were only collected at Station 1. Data and water samples were returned to the ADF&G Kodiak Island Laboratory (Kodiak, AK) for analyses.

Temperature, Dissolved Oxygen, Light, Water Clarity, and Euphotic Volume

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI®[1] meter. Surface temperature readings were confirmed with a YSI 60 pH/temperature meter. Temperature and dissolved oxygen readings were recorded at half-meter intervals to a depth of 5 m and then at 1 m intervals to the lake bottom.

Water transparency was measured at each station using a Secchi disc as described in Ruhl (2013). Measurements of light in the visible spectrum range (400–700 nm), known as photosynthetic active radiation (PAR), were obtained with a Li-Cor® (Li-250) submersible photometer at the lake sampling stations during the monthly sampling schedule. Readings were taken just below the water's surface (subsurface) at half-meter intervals below the water surface until reaching a depth of 5 m, and at 1 m intervals to the lake bottom or to a depth at which the reading was less than 1% of the subsurface reading. Measurements were adjusted by linear regression to the Beer-Lambert equation (Wetzel 1983) to estimate an integrated vertical extinction coefficient (K_d m) for PAR within the euphotic zone, the layer of water from the surface down to 1% of subsurface PAR as

$$K_d \text{ m} = (1/z) \ln (I_z / I_o), \tag{11}$$

where

I_o = light intensity just below the water surface, and

I_z = light intensity at water depth z in meters.

Lake primary production potential for rearing juvenile sockeye salmon was assessed through a euphotic volume calculation as the product of the average euphotic zone depth (EZD) for the 5 monthly sampling periods and lake surface area (Koenings and Burkett 1987).

General Water Chemistry, Phytoplankton and Nutrients

During each survey, water samples were collected at a depth of 1 m below the water's surface using a 4.0 L Van Dorn sampler. Each water sample was emptied into a pre-cleaned

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[1] Product names used in this publication are included for scientific completeness and do not constitute a product endorsement.

polyethylene carboy after being rinsed with sample water, kept cool and dark in transport, and refrigerated at the Kodiak Island Laboratory. Water samples were processed or frozen within 12 hours of arriving at the laboratory. Lake water from the carboy was transferred into a sample rinsed 500 mL bottle, refrigerated, and analyzed for alkalinity and pH. A 250 mL bottle was also rinsed with sample water and filled with unfiltered water from the carboy, frozen, and later analyzed for total Kjeldahl nitrogen (TKN), total phosphorus (TP), and reactive silicon (Si). A total of 2 L of water was filtered using the following 2 different methods for assessing different water quality parameters. The first 1 L sample of lake water was filtered through a rinsed 4.25 cm diameter Whatman® GF/F cellulose fiber filter under 15 psi vacuum for filtrate collection. The filtrate was then analyzed for total filterable phosphorus (TFP), filterable reactive phosphorus (FRP), nitrate + nitrite (NO_3^- + NO_2^-; N+N), and ammonia (NH_4^+; TA). The second 1 L sample of lake water was filtered through another Whatman® fiber filter pad with the addition of approximately 5 mL of magnesium carbonate ($MgCO_3$) added to the final 50 mL of water near the end of the filtration process to act as a preservative. The filtrate was discarded and the fiber filter was retained and frozen on a petri dish for chlorophyll-*a* (chl-*a*) and phaeophytin (pheo-*a*) analysis.

The pH of water samples from samples collected at 1 m was measured in situ with a YSI 60 pH meter. The pH of water samples collected at depth was measured with an Oakton pHTestr 30 meter. Alkalinity (mg/L as $CaCO_3$) was determined from 100 mL of unfiltered water titrated with 0.02 N H_2SO^4 to a pH of 4.5.

TA, N+N, and Si were analyzed using a SEAL® Analytical AA3 segmented flow autoanalyzer by methods described in the manufacturer's chemistry protocols described in Ruhl (2013). TP, TFP, and FRP were analyzed using manual methods and autoanalyzer methods described in Ruhl (2013) and Koenings et al. (1987). TKN was determined at the University of Georgia Feed and Environmental Water Laboratory using the 4500-N D conductimetric method of TKN determination.

Total nitrogen (TN), the sum of TKN and N+N, and the ratio of TN to TP were calculated for each sample. Chlorophyll *a* (chl *a*) is the primary photosynthetic pigment in plants and is commonly used as an index of phytoplankton abundance. Samples of chl *a* were prepared for analysis by separately grinding each frozen filter containing the filtrate in 90% buffered acetone using a mortar and pestle and then refrigerating the resulting slurry from each sample in separate 15 mL glass centrifuge tubes for 2 to 3 hours to ensure maximum pigment extraction. Pigment extracts were centrifuged, decanted, and diluted to 15 mL with 90% acetone. The extracts were analyzed with a SG5 (spectrophotometer) using methods described in Ruhl (2013) and Koenings et al. (1987). Concentrations of phaeophytin *a* (phaeo *a*), a common degradation product of chl *a*, were simultaneously estimated during the spectrophotometer analysis of chl *a*. The ratio of chl *a* to phaeo *a* was calculated to provide an indicator of phytoplankton physiological condition.

Zooplankton

Vertical zooplankton hauls were made at each station using a 0.2 m diameter conical net with 153 µm mesh. The net was pulled manually at a constant speed (~0.5 m/second) from approximately 1 m off the lake bottom to the surface. The contents from each tow were emptied into a 125 mL polyethylene bottle and preserved in 10% buffered formalin. Cladocerans and copepods were identified to genus using taxonomic keys in Edmondson (1959), Thorp and Covich (2001), and Wetzel (1983). Zooplankton lengths were measured in triplicate 1 mL subsamples taken with a Hansen-Stempel pipette and placed in a Sedgewick-Rafter counting chamber. Zooplankton were grouped at the genus level and measured to the nearest 0.01 mm. The standard deviation (SD) of the lengths (L) of up to 15 individuals was estimated. This value was then used to estimate the appropriate sample size (*n*) by applying it to a *t*-test (t) with a 0.05 significance level and relative to 10% variation from the mean measured length calculated as

$$n=[(\mathrm{t} \times \mathrm{SD})/(0.1 \times \mathrm{L})]^2. \qquad (12)$$

Biomass was estimated from species-specific linear regression equations of length and dry weight derived by Koenings et al. (1987). For each survey, average density and biomass from the two stations were calculated for each genera.

Phytoplankton

For phytoplankton analysis, 4 mL of Lugol's acetate was added to 200 mL of water withdrawn from the contents of the 1 m water sample carboy. Samples were sent to BSA Environmental Services Incorporated (Beachwood, Ohio) for analysis.

RESULTS

SMOLT ASSESSMENT

Smolt Capture

The trap was fished continuously from 7 May until it was removed for the season on 27 June 2014 (Figures 5 and 6). A total of 25,889 sockeye salmon smolt were captured in the downstream inclined-plane trap (Tables 1 and 2).

The average number of sockeye salmon smolt captured in the downstream inclined-plane trap from 2010 to 2014 was 36,748, ranging from 22,092 in 2012 to 54,409 in 2011 (Appendix A1). On the day the trap was installed, 487 outmigrating smolt were captured (Table 2). Because of the early outmigration start, a time series analysis was utilized to back calculate the total number of smolt that would have been captured prior to trap deployment and estimate run timing. The time series analysis projected trap captures back to April 24 and increased the trap catch by 1,782 fish for a season total of 27,671 smolt (Tables 1 and 2; Figure 7).

Trap Efficiency and Mark-Recapture Abundance Estimation

Daily catches of sockeye salmon smolt in the beginning of the outmigration were larger than expected, which indicated the outmigration began earlier than anticipated, prompting a time series analysis (24 April–11 May; Tables 1 and 2). As a result, the trap efficiency estimated for 8 May was applied to the first stratum assuming identical trapping conditions. Standard mark–recapture trap efficiency methods were used to generate the total outmigration for the remaining 5 strata. The 6 trap efficiency tests ranged from 22.8% in Stratum 5 (6 June–19 June) to 7.0% in Stratum 2 (12 May–18 May; Table 2; Figure 6). In 2014, mean estimated trap efficiency was below average at 13.1% (2003–2014 at 16.1%; 2010–2014 at 14.2%; Appendix A1).

The estimated total sockeye salmon smolt outmigration from Afognak Lake in 2014 was 218,239 (95% CI 155,141–281,338; Table 1). Peak smolt outmigration occurred 6 June to 19 June, with the outmigration tapering off 20 June to 26 June (Table 2).

Life History-Based Abundance Estimation

Using the life history-based abundance method and using the assumptions previously identified, the 2011 escapement of 49,193 adults (brood year 2011) could have produced 452,080 age-2 smolt. The 2012 escapement of 41,553 adults (brood year 2012) could have produced 564,636 age-1 smolt (Table 3; Figure 8). Combining these 2 age classes resulted in an outmigration potential of 1,016,716 smolt from Afognak Lake in spring 2014.

Age, Weight, Length, and Condition Factor

AWL data were obtained from 513 sockeye salmon smolt collected proportionally throughout the trapping period (Table 4). Summing smolt abundance estimates by age class for all 6 mark–recapture strata resulted in 135,410 (62.0%) age-1, 82,830 (38.0%) age-2, and zero (0.0%) age-3 smolt outmigrating to the ocean (Table 5; Figure 9). This was below the 5-year and 12-year averages for age-1 sockeye salmon smolt (2010–2014, 74.8%; 2003–2014, 76.2%) and above the 5-year and 12-year averages for age-2 smolt (2010–2014, 25.1%; 2003–2014, 23.8%, Appendix A2).

Age-1 sockeye salmon smolt had a mean weight of 3.5 g, a mean length of 74 mm, and a mean *K* of 0.83. Sampled age-2 sockeye salmon smolt had a mean weight of 4.1 g, a mean length of 81 mm, and a mean *K* of 0.78. No age-3 sockeye salmon smolt were sampled in 2014.

ADULT SALMON ASSESSMENT

Enumeration

The first salmon passed through the counting gates on 11 May. Adult salmon were enumerated on a daily basis until 23 August when the weir was removed with 36,345 sockeye, 18,408 pink, 3,224 coho, and 1 Chinook salmon escaping into the Afognak system (Table 6; Figure 10; Appendix A5; Fuerst 2014). Sockeye salmon escapement peaked between 31 May and 6 June, when 17,766 fish were enumerated (Table 7). Additionally, 85 steelhead kelts were passed downstream through the weir. The 2014 sockeye salmon escapement count was below the 5-year and above the 10-year average (Appendix A5). The 2014 coho salmon escapement was below the 5-year and 10-year averages (Appendix A5). However, coho salmon escapement enumeration is highly dependent on the date the weir is removed, which will be further examined in the Discussion section.

Age, Sex, and Length Data

A total of 700 adult sockeye salmon were sampled from 18 May through 18 July, resulting in a total of 570 samples where age could be determined from the scales (Table 7). The goal of estimating age composition of the escapement within d=0.07 (95%) confidence was achieved for all ages within each stratum.

The majority (44.7%) of the sockeye salmon escapement was comprised of age-1.3 fish, while 23.0% were age-1.2 fish, 13.4% were age-2.3 fish, and 14.3% were age 2.2 fish (Table 7; Appendix A4). The majority of age-1.2 and age-1.3 fish escaped during late May and early June. The estimated sex composition of the escapement was 49% female and 51% male. Overall average length was 449 mm for all sockeye salmon (Table 8). The Afognak Lake sockeye salmon escapement is typically comprised of ocean-age-3 fish, followed by ocean-age-2 fish (Appendix A14; Figure 14). Ocean-age-1 fish averaged 4.5% of Afognak Lake's escapement, while ocean-age-4 fish make a negligible contribution.

LIMNOLOGICAL ASSESSMENT

Temperature, Dissolved Oxygen, Light, Water Clarity, and Euphotic Volume

Monthly water temperatures at Station 1 taken during limnological sampling ranged from 8.5°C near the lake bottom on 14 May to 15.9°C on 17 August (Figure 11). Seasonal mean water temperatures at 1 m and near the bottom were above the historical average (1989–2013 and 2010–2014; Appendix A6). Mean surface (1 m) temperatures were 11.9°C in the spring, 16.1°C in the summer, and 14.8°C in the fall (Appendix A6).

In 2014, the data logger at 1 m (Station 2) was operated continuously from 16 May to 22 October, recording temperature every hour. For comparison with monthly limnology sampling averages, mean surface (1 m) temperatures were 13.4°C in the spring, 16.7°C in the summer, and 11.8°C in the fall (Table 9). The temperature logger recorded a maximum of 18.0°C in July, a minimum of 7.0°C in October, and an overall mean of 14.3°C. Average spring temperatures recorded by the data logger were greater in 2014 than previous years (2010–2014; Table 9).

Afognak Lake was stratified in July with mixing occurring May-June and August-September (Figure 11). Monthly dissolved oxygen (DO) concentrations at station 1 taken during limnology sampling ranged from 10.9 mg/L at the surface in the spring to 6.5 mg/L near the lake bottom in the summer (Appendix A7). Mean vertical light extinction coefficient was -0.56 m, mean EZD depth was 7.87 m, and mean Secchi disk reading was 4.15 meters (Appendix A8). The estimated euphotic volume (EV) for Afognak Lake was 41.74×10^6 m^3 (Appendix A8). Using the EV model and 800–900 spawners per EV unit resulted in a spawning capacity estimate of 33,369 to 37,540 adults (Koenings and Kyle 1997; Appendix A8).

EZD values recorded in 2014 indicated that, on average, the first 8 m of the water column at the sampling stations were photosynthetically active (Appendix A8). Historical mean EZD values were comparable, with an average of 9 m of the water column being photosynthetically active (1987–2013 and 2010–2014; Appendix A8).

General Water Chemistry and Nutrients

Afognak Lake mean pH was 7.48 and ranged from 7.31 in May to 7.59 in September (Station 1; Table 10; Appendix A9). Mean alkalinity level was 11.4 mg/L and ranged from 8.8 mg/L in May to 13.5 mg/L in September (Table 10). Mean chl-*a* concentration was 1.68 µg/L and ranged from 1.07 µg/L in August to 2.24 µg/L in May (Table 10). Mean phaeo-*a* concentration was 0.34 µg/L and ranged from 0.08 µg/L in July to 0.87 µg/L in September. Mean reactive silicon concentration was 2,312.3 µg/L and ranged from 1,738.3 µg/L in May to 2,850.9 µg/L in June (Table 11).

Mean TP concentration was 3.8 µg/L and ranged from 3.3 µg/L in August to 4.7 µg/L in September (Table 11; Appendix A10). Mean TFP concentration was 1.2 µg/L and ranged from 0.9 µg/L in May and August to 1.6 µg/L in September. Mean FRP concentration was 1.2 µg/L and ranged from 0.7 µg/L in May and June to 2.3 µg/L in September.

Mean TKN concentration was 524.4 µg/L and ranged from 152.0 µg/L in May to 1,147.0 µg/L in June (Table 11; Appendix A10). Mean NH_4^+ concentration was 5.6 µg/L and ranged from 1.5 µg/L in May to 16.3 µg/L in June. Mean $NO_2 + NO_3$ concentration was 13.5 µg/L and ranged from 0.1 µg/L in July to 45.8 µg/L in May. Mean TN concentration was 537.9 µg/L and ranged from 197.8 μg/L in May to 1,152.4 μg/L in June. The overall mean TN to TP ratio, by weight, was 327.8:1 and ranged from 121.7:1 in May to 750.5:1 in June.

Zooplankton

In 2014, overall (stations 1 and 2 averaged) mean zooplankton density was 111,916 no/m^2 (Table 12). All zooplankton were cladocerans (Order Anomopoda and Ctenopoda) or copepods (Order Calanoida, Cyclopoida, and Harpacticoida). Cladocerans were more abundant (76.8% of mean density) than copepods (23.1%). Among the cladocerans, the 2 most abundant groups were *Bosmina* (85.9% of cladocerans; 66.0% of total) and *Daphnia l.* (7.5% of cladocerans; 5.8% of total). Other observed cladoceran genera were various unidentified immature cladocerans (5.1%; 3.9% of total) and *Holopedium* (1.4%; 1.0% of total). Among the copepods, the 2 most abundant groups were the *Epischura* (63.9% of copepods; 14.8% of total) and the pooled category of "other copepods" (36.1% of copepods; 8.4% of total), which was made up mostly of various unidentified nauplii (larvae) or immature copepods. The other copepod genera included *Cyclops*, usually an important component of the zooplankton community in sockeye salmon rearing lakes (6.6% of copepods; 1.5% of total), and *Diaptomus* (1.7% of copepods; 0.4% of total).

In 2014, the seasonal mean weighted zooplankton biomass was 136.3 mg/m^2 and was mostly comprised (53.1% of mean total biomass) of copepods (Table 13). The copepod genus *Epischura* represented 48.4% of the biomass, followed by the cladoceran genus *Bosmina* (39.3%). The remaining biomass was composed of *Daphnia* (5.6%), *Cyclops* (2.8%), *Holopedium* (2.0%), and *Diaptomus* (1.4%).

The copepod *Diaptomus* was the largest zooplankton taxa measured, with a weighted mean length of 0.97 mm (Table 14). Mean lengths of the remaining zooplankton, in decreasing size, were 0.92 mm for the copepod *Epischura*, 0.65 mm for the copepod *Cyclops,* 0.56 mm for the cladoceran *Daphnia*, 0.47 mm for the cladoceran *Holopedium*, and 0.28 mm for the cladoceran *Bosmina*. All mean weighted lengths included ovigerous individuals.

For historical comparison, using only the predominant crustaceans at Station 1, the post fertilization (2001–2013) average weighted mean zooplankton density was 93,650 no/m^2 (Appendices A11 and A12). The 2014 average weighted mean zooplankton density was 125,210 no/m^2, also greater than the 5-year average of 89,053 no/m^2. The post fertilization average zooplankton biomass was 122 mg/m^2, which was less than the 2014 mean total zooplankton biomass of 180 mg/m^2.

Phytoplankton

In 2014, the seasonal mean phytoplankton biovolume was 324,786,960 μm^3/L. Phytoplankton species composition was predominately composed of Bacillariophyta (Diatoms; 53.3%; 173,028,927 μm^3/L) and Pyrrhophyta (Dinoflagellates; 82,351,757 μm^3/L; 25.4%; Table 15). From 2010 to 2014, total biovolume fluctuated tremendously, ranging from 654,787 μm^3/L in 2011 to 324,786,960 μm^3/L in 2014 (Appendix A15). Biovolume estimates from 2010 to 2013 were reported as biomass, but for observations of whole phytoplankton communities, biovolume is a more accurate descriptor; all phytoplankton data presented here are updated and correctly presented.

DISCUSSION

SMOLT ASSESSMENT

This was the fourth year using 2-trap mark–recapture methods to estimate the Afognak sockeye salmon smolt outmigration. The previous 8 years employed 1-site mark–recapture methods (Baer 2011). Despite changes in field personnel, project biologists, trapping methods, and varying environmental conditions, a mean trap efficiency of 16.1% (2003–2014) has been within the targeted range of 15% to 20% and ranged from 11.4% to 19.9% annually (Appendix A1). Trap efficiencies by strata were comparable to previous years, suggesting reliable and consistent mark-recapture estimates (Appendix A1).

The Afognak Lake sockeye salmon smolt outmigration was the third lowest estimate since the mark–recapture project was initiated in 2003. The outmigration estimate of 218,239 was below the most recent 5-year average (258,043) and below the average for all trapping years (334,648; Appendices A1 and A2). The trap catch of 27,671 was below average but was within the mean standard deviation for an estimate at this site (5-year; Appendix A1).

The Afognak Lake sockeye salmon smolt outmigration started prior to trap installation. The day the trap was installed, 487 smolt were captured, indicating a portion of the run was missed (Table 2). The impetus of the early movement was likely due to a warmer spring and above-average lake temperatures. It has been reported that salmon migrate earlier after a mild spring than a cold one (Burgner 1962) and smolt emigrate once lake temperatures rise above 4°C (Hartman et al. 1967). The temperature of the river upon trap installation on May 7th was 8°C and by May 27th increased to 15°C as water levels decreased by 190 cm during that same period. The low water conditions likely led to below average trap efficiencies for 2 of the 6 sampling stratum (Table 1). To address the possibility of an early smolt outmigration in 2015, the smolt traps will be installed 2 weeks earlier than average.

Timing of the outmigration began and ended earlier than average, with older smolt migrating earlier (Figures 7 and 9). Age compositions were consistent with past years. Age-1 outmigrating smolt had the greatest average length, weight, and *K* observed in the last 5 years (2010–2014; Table 4; Appendix A3). Since 2010, outmigrating age-1 smolt *K* has been slightly above the 2003-2014 average (Figure 19; Appendix A3). The dominance and robustness of age-1 smolt typically indicates favorable freshwater rearing conditions (Koenings and Kyle 1997). The high *K* is likely a result of the low population size and reduced competition for resources.

As in previous reports, life history-based population estimates were calculated as a comparison to the mark–recapture estimates. Life history-based abundance estimates have been greater than mark–recapture abundance estimates in 9 years (2003, 2006–2008, and 2010–2014) and less than mark–recapture abundance estimates in 3 years (2004, 2005, and 2009). From 2012 to 2014, life history-based estimates have been far greater than mark–recaptures estimates (Table 3; Figure 8; Appendices A1 and A2).

Values used to calculate the life history-based estimate were derived from a variety of lakes with some of the lakes being larger and more productive, with rearing conditions that are not similar to Afognak Lake. With 12 years of reliable smolt outmigration data from Afognak Lake, we hope to better predict freshwater (egg to smolt) survival at smaller lakes to compare with survival rates at larger, productive lakes (Appendix A16). Based on the mark–recapture outmigration estimates, sockeye salmon egg to smolt survival averaged 0.9% and ranged from

0.1% to 1.8% (2003–2013; Appendix A16). Excluding the last 3 years (2012–2014) where the mark–recapture and life history-based estimates diverge, egg to smolt survival averaged 1.1%. For comparison, the life history-based estimates for large, productive lakes averaged 1.45%. Given the tendency to overestimate smolt production using a survival rate of 1.45%, future life history-based estimates should be lowered to 1.1% following Afognak Lake data.

Zooplankton biomass measurements, 2001 to 2014, from limnological Station 1 have estimated low biomasses (71-205 mg/m^2; Appendix A11). The low average zooplankton density, biomass, and sizes indicate top-down pressure and competitive feeding conditions (Appendices A11 and 12), yet juvenile sockeye in 2014 had the best age-1 smolt condition since the inception of the project (2003), which indicates productive rearing conditions. Diet analyses from 2009 to 2013 of rearing Afognak Lake sockeye salmon captured in the shoals revealed that they forage for insects June through August (N. Richardson, ADF&G, unpublished data). Considering smolt robustness, it is likely that significant mortality occurred early, when juveniles shifted their diet from zooplankton to insects or prior to dependence on zooplankton.

It is possible that predation and competition from juvenile coho feeding in Afognak Lake contributed to poor egg to smolt survival. Ruggerone and Rogers (1992) found significant predation (up to 59% of sockeye salmon fry) by juvenile coho salmon on sockeye salmon fry in Chignik Lake. In 2013, juvenile coho salmon were collected from the shoals in May during the course of juvenile sockeye salmon sampling. The examination of juvenile coho salmon stomach contents confirmed predation on juvenile sockeye salmon during the juvenile lake assessment study (Thomsen et al. 2014). Of the 25 coho salmon stomachs examined, 22% had sockeye fry present, and 1 had 11 fry. More extensive sampling in terms of increased sample size and stations sampled should be considered in the future to determine the significance of juvenile coho salmon predation on lake rearing sockeye salmon.

Dolly Varden may also contribute to the predation in Afognak Lake, but Roelofs (1964) examined this possibility and found no merit. Roelofs observed the bulk of the Dolly Varden to have migrated out of the river prior to the smolt outmigration. Roelofs examined numerous Dolly Varden stomachs and found no sockeye salmon present. Additionally, he found that Dolly Varden return to the lake in July, and examination of the stomachs indicated that they did not feed in the river.

ADULT SALMON ASSESSMENT

The adult sockeye salmon escapement into Afognak Lake has consistently met the lower escapement goal in the last 10 years (Appendix A13; Figure 13). Additionally, the sockeye salmon escapement has met or been near the upper bound of the BEG in the last 5 years.

Return per spawner (R/S) for sockeye salmon in Afognak Lake tends to inversely mirror escapement data, increasing when escapements are low and decreasing when escapements are large (Figure 15). Afognak Lake had some of its greatest escapements on record from 1990 to 2000, followed by its lowest escapements from 2001 to 2007 (Appendix A13). Concurrent with fertilization, backstocking occurred in 1992, 1994, and 1996 to 1998, when approximately 1.53 million fingerling and 523,000 presmolt were released into Afognak Lake (Honnold and Schrof, 2003). The increased population size of rearing juveniles from the combination of high escapements and backstocking elevated competition for food resources and limited overall production, as evidenced by low R/S, despite fertilization.

Specifically, the average R/S for all years in Afognak Lake is 1.4, ranging from 0.1 to 3.9 (Appendix A13). The last 5 years of fertilization (1996-2000) average R/S was .3 but typically achieved replacement levels (>1) 2 years after fertilization ceased. The relationship between escapements and R/S (Figure 15; Appendix A13) shows that Afognak Lake sockeye salmon production is density-dependent and caution should be taken to avoid overescapement and the introduction of supplemental fish via backstocking in the future.

Although the commercial harvest of 9,753 sockeye salmon was below average (11,986; 1978–2013), it was above the most recent 5-year (8,615) and above pre-fertilization (5,507) averages (1978–1988; Table 6; Jackson et al. 2014). These pre-fertilization averages exclude 1989 when the commercial fishery was closed due to the Exxon Valdez oil spill.

Sufficient sockeye salmon smolt outmigration data have been collected from Afognak Lake to begin determining ocean survival (2000–2014). Comparison of smolt outmigration numbers and ages with the number and ages of returning adults was assessed for 6 or 7 years, depending on smolt age. Survival of age-1 smolt was the greatest, with an average smolt to adult survival (ocean survival) of 17.3%, ranging from 5.9 to 40.3% (Appendix A16). Average ocean survival for age-2 smolt was 16.3%, ranging from 1.1 to 35.1%. Overall, smolt survival averaged 15.9% (2003–2008).

Monitoring of adult coho salmon escapement into Afognak Lake is secondary to monitoring sockeye salmon escapement. Because removal of the weir is dependent on budgetary constraints and not assessing coho salmon escapement, coho salmon escapement counts through the weir are inaccurate and dependent on run timing and the date of weir removal.

Coho salmon escapement has averaged approximately 6,761 fish since 1978 and currently has no escapement goal established. An SEG of 3,500–8,000 (passage through the weir by 15 September) was reported by Nelson and Lloyd (2001) but was eliminated due to early weir removal (Nelson et al. 2005). In 2014, the coho salmon escapement of 3,224 was below average but the most recent 5 years have averaged 7,001 coho (Appendix A5; Figure 16).

In light of concerns about possible competition and predation on juvenile sockeye salmon in Afognak Lake by juvenile coho salmon, ADF&G plans to extend weir operations in 2015 to more closely monitor the adult coho salmon escapement.

LIMNOLOGICAL ASSESSMENT

Temperatures in the lake were above a 25-year average (1989–2013) during seasonal limnological sampling (Appendix A6) and above average 3 of the last 4 years of temperature data using a logger (Table 9). DO values were slightly below the 25-year average (Appendix A7). Euphotic zone depth (EZD) values indicated that, on average, the first 7.9 m of the water column at the sampling stations were photosynthetically active. With an average lake depth of 8.6 m, this suggests that the majority of Afognak Lake was capable of primary production throughout the sampling season.

Seasonal measurements of mean nutrient and algal pigment concentrations generally showed little variation over the sampling season, with the exception of nitrogen components. From a historical perspective, pH and alkalinity were slightly above average, which can be expected with an increase in the lake temperature and phytoplankton production (Wetzel 1983; Appendix A9). Phosphorus components were below the historical average (Appendix A10), and nitrogen components were consistent, with the exception of TKN, which was over 3 times the historical average and the highest value observed for the second consecutive year. TKN in part represents organic forms of nitrogen. Organic nitrogen can be introduced into lakes via precipitation, nitrogen-fixing bacteria, blue-green algae, and groundwater runoff (Wetzel 1983). The elevated TKN average for 2014 was driven by a 1,147 µg/L measurement taken on 19 June (Table 11). There were 3 significant precipitation events just prior to the 19 June limnological sample. The first event, on 28 May, increased the stream level by 40 cm. The second considerable occurrence, on 6 June, heightened the stream level by 150 cm, and the last substantial episode 2 days prior to the June sample raised the stream by 120 cm. In light of the major rain events leading up to the June sample, and blooms of blue-green algae being negligible throughout the season, it is probable that TKN concentrations were elevated due to groundwater runoff and precipitation.

Chlorophyll and phaeophytin were comparable to their historical averages. Similar to 2013, the abundance of nitrogen and decreased phosphorus concentration, coupled with average chl-*a* (primary production), suggests that phosphorus was well-utilized and adequate rates of photosynthesis occurred as evidenced by the increased phytoplankton biomass.

Typically, phytoplankton communities are dominated by either diatoms or flagellates (Officer and Ryther 1980). Diatoms are the preferred phytoplankton prey for zooplankton in northern lakes and tend to dominate in oligotrophic systems with sufficient silicon concentration (Officer and Ryther 1980). Several of the larger oligotrophic lakes in Kodiak are predominately composed of diatom phytoplankton communities (Finkle 2013; Thomsen 2011). Low nutrient levels favor some diatom species because they can store phosphorus, unlike other phytoplankton taxa (Wehr and Sheath 2003). Dominant species of phytoplankton in Afognak Lake have varied over the 5 years of sample collection, but the community typically has been composed of species that can tolerate oligotrophic nutrient levels and frequent physical disturbances (Wehr and Sheath 2003).

Mean phytoplankton biovolume in Afognak Lake has increased tremendously since 2011; the 2014 biovolume was nearly 300 times that of 2012 and almost 500 times that of 2011 (Appendix A15). Likewise, mean nitrogen (TKN) concentration has increased immensely since 2011. Because the predominant phytoplankton species are more responsive to environmental variables, and it is unlikely TKN concentrations increased from blue-green algae metabolizing nitrogen, precipitation events appear to be a driver of nitrogen and phytoplankton dynamics. Considering the record rain and snow fall that occurred in Kodiak during 2012 and 2013 (ACRC 2013), this hypothesis is plausible.

The seasonal mean zooplankton density and biomass estimates were low in Afognak Lake over the sampling season and slightly above the 5-year average. Recent biomasses continue to remain near the starvation level of 100 mg/m^2 for rearing salmonids (2010–2014; Mazumder and Edmundson 2002). Data from the cladoceran *Bosmina* suggested that juvenile sockeye salmon may overgraze this key taxa; *Bosmina* were small (mean length of 0.29 mm) and well below the juvenile sockeye salmon minimum elective feeding threshold of 0.40 mm (Kyle 1992). The low biomass of zooplankton in Afognak Lake may also be the result of competition for resources with aquatic insects, inedible phytoplankton, or temperature (Thorp and Covich 2001).

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TABLES AND FIGURES

Table 1.–Estimated abundance of sockeye salmon smolt outmigrating from Afognak Lake, 2014.

Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Carlson trap efficiency (%)	Estimate (U_h)	Variance (U_h)	95% confidence interval	
									Lower	Upper
1	24-Apr	11-May	4,859	195	36	18.8	25,777	14,298,284	18,366	33,189
2	12-May	18-May	3,767	525	36	7.0	53,565	70,884,179	37,063	70,066
3	19-May	23-May	2,643	527	57	11.0	24,062	8,927,203	18,206	29,918
4	24-May	5-Jun	6,834	332	33	10.2	66,965	115,620,744	45,890	88,040
5	6-Jun	19-Jun	8,777	271	61	22.8	38,566	18,364,650	30,167	46,966
6	20-Jun	26-Jun	791	234	19	8.5	9,304	3,866,804	5,450	13,158
Total			27,671	2,085	242	13.1	218,239	231,961,865	155,141	281,338
							SE=	15,230		

Note: The parameters h, M_h, m_h, U_h, and u_h are used to calculate the outmigration estimate and are defined on page 6.

Table 2.–Sockeye salmon smolt catch, number of AWL samples collected, mark-recapture releases, recoveries, and trap efficiency estimates from Afognak River by stratum, 2014.

	Sockeye smolt		Trap efficiency test		
Date[a]	Daily	Samples	Releases[b]	Recoveries	Efficiency
24-Apr	24	0	0	0	18.8%
25-Apr	31	0	0	0	18.8%
26-Apr	38	0	0	0	18.8%
27-Apr	48	0	0	0	18.8%
28-Apr	61	0	0	0	18.8%
29-Apr	77	0	0	0	18.8%
30-Apr	97	0	0	0	18.8%
1-May	122	0	0	0	18.8%
2-May	154	0	0	0	18.8%
3-May	193	0	0	0	18.8%
4-May	244	0	0	0	18.8%
5-May	307	0	0	0	18.8%
6-May	387	0	0	0	18.8%
7-May	487	10	0	0	18.8%
8-May	885	20	217	18	18.8%
9-May	733	15	0	8	18.8%
10-May	482	10	0	10	18.8%
11-May	490	10	0	0	18.8%
Total stratum 1	4,859	65	217	36	18.8%
Stratum 2					
12-May	620	15	547	30	7.0%
13-May	487	10	0	4	7.0%
14-May	364	10	0	2	7.0%
15-May	547	10	0	0	7.0%
16-May	405	10	0	0	7.0%
17-May	561	15	0	0	7.0%
18-May	783	15	0	0	7.0%
Total stratum 2	3,767	85	547	36	7.0%

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Table 2.–Page 2 of 3.

	Sockeye smolt		Trap efficiency test		
Date[a]	Daily	Samples	Releases[b]	Recoveries	Efficiency
19-May	1,367	20	549	43	11.0%
20-May	241	5	0	3	11.0%
21-May	318	10	0	11	11.0%
22-May	312	0	0	0	11.0%
23-May	405	20	0	0	11.0%
Total stratum 3	2,643	55	549	57	11.0%
Stratum 4					
24-May	397	10	346	1	10.2%
25-May	803	10	0	10	10.2%
26-May	689	15	0	8	10.2%
27-May	936	20	0	7	10.2%
28-May	95	0	0	1	10.2%
29-May	416	10	0	0	10.2%
30-May	980	20	0	0	10.2%
31-May	609	15	0	1	10.2%
1-Jun	765	15	0	1	10.2%
2-Jun	301	5	0	4	10.2%
3-Jun	176	0	0	0	10.2%
4-Jun	316	15	0	0	10.2%
5-Jun	351	10	0	0	10.2%
Total stratum 4	6,834	145	346	33	10.2%

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Table 2.–Page 3 of 3.

	Sockeye smolt		Trap efficiency test		
Date[a]	Daily	Samples	Releases[b]	Recoveries	Efficiency
6-Jun	540	0	475	12	22.8%
7-Jun	691	10	0	27	22.8%
8-Jun	1,528	30	0	13	22.8%
9-Jun	972	20	0	8	22.8%
10-Jun	411	10	0	1	22.8%
11-Jun	647	15	0	0	22.8%
12-Jun	104	0	0	0	22.8%
13-Jun	569	15	0	0	22.8%
14-Jun	1,243	0	0	0	22.8%
15-Jun	383	5	0	0	22.8%
16-Jun	405	15	0	0	22.8%
17-Jun	738	15	0	0	22.8%
18-Jun	355	10	0	0	22.8%
19-Jun	191	0	0	0	22.8%
Total stratum 5	8,777	145	475	61	22.8%
Stratum 6					
20-Jun	300	10	366	1	8.5%
21-Jun	181	0	0	14	8.5%
22-Jun	96	0	0	4	8.5%
23-Jun	90	15	0	0	8.5%
24-Jun	53	0	0	0	8.5%
25-Jun	36	0	0	0	8.5%
26-Jun	35	0	0	0	8.5%
Total stratum 6	791	25	366	19	8.5%
Total strata 1–6	27,671	520	2,500	242	13.1%

[a] 24-April to 6-May are time series estimates.

[b] The number of marked releases for each strata were adjusted using delayed mortality tests.

Table 3.–Theoretical production of Afognak Lake sockeye salmon eggs, emergent fry, and smolt by age from brood years 2011 and 2012 and predicted smolt outmigration for 2014.

Production		Brood year		Estimate 2014
Parameter	Assumption	2011	2012	FW-age-1 and -2 smolt
Escapement		49,193	41,553	
Females spawners	61% (2011) 59% (2012)[a]	30,008	24,516	
Deposited eggs	2,697 (2011) 2,527 (2012)[b]	80,930,848	61,952,614	
Emergent fry	7% egg-to-fry survival[c]	5,665,159	4,336,683	
Smolt	21% fry-to-smolt survival[d]	1,189,683	910,703	
2014 smolt emigration	62% FW-age-1, 38% FW-age-2 [e]	452,080	564,636	1,016,716

[a] Female sex composition derived from 2011 and 2012 sex data obtained from adult age, length, and sex sampling.

[b] Actual fecundity of Afognak Lake sockeye salmon as reported from Pillar Creek Hatchery (2011 and 2012).

[c] Egg to fry survival assumption from Drucker (1970), Bradford (1995), and Koenings and Kyle (1997).

[d] Fry to smolt survival assumptions from Koenings and Kyle (1997).

[e] Age composition assumptions derived from the average 2014 smolt age class estimate.

Table 4.–Length, weight, and condition of sockeye salmon smolt, by stratum and age, from the Afognak River, 2014.

Stratum	Date		Sample	Length (mm)		Weight (g)		Condition (*K*)	
	Starting	Ending	Size	Mean	SE	Mean	SE	Mean	SE
				Age-1					
1	24-Apr	11-May	1	72.0	0.00	2.8	0.00	0.75	0.000
2	12-May	18-May	20	68.4	1.17	2.5	0.14	0.80	0.034
3	19-May	23-May	29	70.6	0.88	2.9	0.09	0.82	0.017
4	24-May	5-Jun	134	71.1	0.30	3.0	0.04	0.83	0.008
5	6-Jun	19-Jun	144	78.6	0.31	4.4	0.05	0.90	0.007
6	20-Jun	26-Jun	25	83.5	0.66	5.1	0.14	0.88	0.017
Totals			353	74.0	0.55	3.5	0.08	0.83	0.014
				Age-2					
1	24-Apr	11-May	61	79.9	0.45	3.8	0.06	0.75	0.013
2	12-May	18-May	64	78.2	0.44	3.7	0.05	0.77	0.013
3	19-May	23-May	26	80.2	0.60	3.9	0.09	0.75	0.016
4	24-May	5-Jun	8	78.6	1.02	3.8	0.21	0.78	0.031
5	6-Jun	19-Jun	1	86.0	0.00	5.5	0.00	0.86	0.000
6	20-Jun	26-Jun	0						
Totals			160	80.6	0.50	4.1	0.08	0.78	0.015
				Age-3					
1	24-Apr	11-May	0						
2	12-May	18-May	0						
3	19-May	23-May	0						
4	24-May	5-Jun	0						
5	6-Jun	19-Jun	0						
6	20-Jun	26-Jun	0						
Totals			0						

Table 5.–Estimated outmigration abundance of Afognak Lake sockeye salmon smolt by time period (stratum) and freshwater age class, 2014.

	Date			Age			
Stratum	Starting	Ending		1	2	3	Total
1	24-Apr	11-May	Number	413	25,365	0	25,777
			Percent	1.6%	98.4%	0.0%	
2	12-May	18-May	Number	12,789	40,775	0	53,565
			Percent	23.9%	76.1%	0.0%	
3	19-May	23-May	Number	11,228	12,835	0	24,062
			Percent	46.7%	53.3%	0.0%	
4	24-May	5-Jun	Number	63,364	3,601	0	66,965
			Percent	94.6%	5.4%	0.0%	
5	6-Jun	19-Jun	Number	38,312	254	0	38,566
			Percent	99.3%	0.7%	0.0%	
6	20-Jun	26-Jun	Number	9,304	0	0	9,304
			Percent	100.0%	0.0%	0.0%	
Total			Number	135,410	82,830	0	218,239
			Percent	62.0%	38.0%	0.0%	

Table 6.–Afognak Lake sockeye salmon escapement, harvest, and total run estimates, 2010–2014.

		Harvest [a]			
Year	Escapement	Commercial [b]	Subsistence [c]	Total	Total Run
2010	52,255	9,755	2,146	11,901	64,156
2011	49,193	13,858	1,978	15,836	65,029
2012	41,553	3,398	1,731	5,129	46,682
2013	42,153	6,311	2,012	8,323	50,476
2014	36,345	9,753	2,678	12,431	48,776
Average (2010–2014)	44,300	8,615	1,846	10,461	54,761

[a] Sport harvest data does not have enough respondents to provide reliable estimates and was determined to be negligible.

[b] Statistical fishing section 252-34 (Southeast Afognak Section).

[c] Data as of 03/15/2015 from ADF&G subsistence catch database.

Table 7.–Afognak Lake adult sockeye salmon escapement by statistical week and age class, 2014.

Date		Sample		Age							
Starting	Ending	size		0.2	1.1	1.2	1.3	2.1	2.2	2.3	Total fish
10-May	16-May	0	Percent	0.0	0.0	6.4	78.7	0.0	6.4	8.5	
			Numbers	0	0	1	11	0	1	1	14
17-May	23-May	0	Percent	0.0	0.0	6.4	78.7	0.0	6.4	8.5	
			Numbers	0	0	28	343	0	28	37	436
24-May	30-May	47	Percent	0.0	0.0	7.6	76.6	0.0	6.9	8.9	
			Numbers	0	0	320	2,375	0	257	309	3,260
31-May	6-Jun	188	Percent	0.0	0.0	22.4	50.2	0.0	13.2	14.2	
			Numbers	0	0	4,559	7,712	0	2,529	2,966	17,766
7-Jun	13-Jun	96	Percent	0.2	0.6	30.6	35.7	0.0	14.9	18.1	
			Numbers	7	21	777	926	0	370	430	2,531
14-Jun	20-Jun	0	Percent	0.7	2.0	31.4	41.1	0.0	13.2	11.6	
			Numbers	12	37	575	753	0	242	212	1,832
21-Jun	27-Jun	100	Percent	0.8	9.1	28.5	41.1	2.2	11.9	6.3	
			Numbers	30	250	1,061	1,512	53	429	242	3,577
28-Jun	4-Jul	35	Percent	0.2	26.9	18.0	30.0	8.9	11.9	4.1	
			Numbers	4	397	314	509	129	192	70	1,616
5-Jul	11-Jul	69	Percent	0.0	10.4	17.6	37.7	3.5	19.6	11.1	
			Numbers	0	204	350	779	60	409	232	2,035
12-Jul	18-Jul	35	Percent	0.0	13.9	11.9	39.9	0.2	22.6	11.4	
			Numbers	0	210	177	599	3	341	172	1,502
19-Jul	25-Jul	0	Percent	0.0	14.3	11.4	40.0	0.0	22.9	11.4	
			Numbers	0	68	55	192	0	109	55	479
26-Jul	1-Aug	0	Percent	0.0	14.3	11.4	40.0	0.0	22.9	11.4	
			Numbers	0	95	76	265	0	151	76	662
2-Aug	8-Aug	0	Percent	0.0	14.3	11.4	40.0	0.0	22.9	11.4	
			Numbers	0	80	64	225	0	128	64	562
9-Aug	15-Aug	0	Percent	0.0	14.3	11.4	40.0	0.0	22.9	11.4	
			Numbers	0	7	5	19	0	11	5	48
16-Aug	22-Aug	0	Percent	0.0	14.3	11.4	40.0	0.0	22.9	11.4	
			Numbers	0	1	1	2	0	1	1	6
23-Aug	29-Aug	0	Percent	0.0	14.3	11.4	40.0	0.0	22.9	11.4	
			Numbers	0	3	2	8	0	4	2	19
		570	Percent	0.1	3.8	23.0	44.7	0.7	14.3	13.4	100.0
			Numbers	54	1,373	8,365	16,230	245	5,204	4,874	36,345

Table 8.–Mean length of Afognak Lake adult sockeye salmon escapement by sex and age class, 2014.

	Age							
	0.2	1.1	1.2	1.3	2.1	2.2	2.3	Total
				Males				
Mean length (mm)	460.0	331.4	402.4	497.2	340.7	413.4	495.7	431.7
Standard error	0.00	4.82	5.32	5.44	14.78	8.07	10.5	4.37
Range	460–460	270–380	310–540	390–610	280–390	315–550	395–600	270–610
Sample size	1	25	96	84	7	53	22	288
				Females				
Mean length (mm)	0.0	0.0	447.9	474.6	0.0	446.4	464.3	466.8
Standard error	0.00	0.00	4.69	3.38	0.00	6.91	6.78	4.41
Range			400–505	400–590		385–495	400–590	385–590
Sample size	0	0	35	172	0	28	47	282
				All				
Mean length (mm)	460.0	331.4	414.5	482.0	340.7	424.8	474.3	449.1
Standard error	0.00	4.82	4.45	2.96	14.78	6.03	5.91	2.65
Range	460–460	270–380	310–540	390–610	280–390	315–550	395–600	270–610
Sample size	1	25	131	256	7	81	69	570

Table 9.–Data logger temperatures (°C) at 1 m water depth, station 2, Afognak Lake, 2010–2014.

	Temperature (°C)														
	Average					Maximum					Minimum				
Month	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
May	7.3	7.3	7.3	8.1	13.1	9.2	9.9	9.5	10.6	14.2	5.9	6.6	5.7	7.1	12.0
June	11.3	11.0	12.3	13.3	13.6	13.5	13.7	16.7	17.4	15.6	8.8	8.5	8.1	9.0	12.8
July	14.0	15.1	14.4	17.5	16.8	15.7	17.1	17.3	21.8	18.0	12.4	13.1	12.4	14.3	15.3
August	14.8	15.8	14.8	16.1	16.6	16.1	17.6	16.3	18.8	17.9	14.0	14.5	14.3	15.2	15.9
September	14.3	12.4	12.5	14.5	14.6	15.7	14.8	15.0	15.9	15.8	11.8	10.7	9.8	13.3	12.1
October	9.9	10.4	9.4	–	9.0	11.8	10.7	9.9	–	11.9	8.2	10.0	9.2	–	7.0
Spring (May–June)	9.3	9.1	9.8	10.7	13.4	13.5	13.7	16.7	17.4	15.6	5.9	6.6	5.7	7.1	12.0
Summer (July–Aug)	14.4	15.4	14.6	16.8	16.7	16.1	17.6	17.3	21.8	18.0	12.4	13.1	12.4	14.3	15.3
Fall (Sept–Oct)	12.1	11.4	11.0	14.4	11.8	15.7	14.8	15.0	15.9	15.8	8.2	10.0	9.2	13.3	7.0
Season (May–Oct)	12.3	12.8	12.6	14.4	14.3	16.1	17.6	17.3	21.8	18.4	5.9	6.6	5.7	7.1	6.9

Note: Spring consists of May–June, Summer consists of July–August, and Fall consists of September–October.

Table 10.–General water chemistry and algal pigment concentrations at 1 m water depth, station 1, Afognak Lake, 2014.

Date	pH (units)	Alkalinity (mg/L)	Chlorophyll *a* (µg/L)	Phaeophytin *a* (µg/L)
14-May	7.31	8.8	2.24	0.22
19-Jun	7.47	11.0	2.14	0.11
14-Jul	7.48	10.5	1.60	0.08
19-Aug	7.55	13.3	1.07	0.43
15-Sep	7.59	13.5	1.37	0.87
Average	7.48	11.4	1.68	0.34
SD	0.11	2.0	0.50	0.33

Table 11.–Seasonal phosphorus and nitrogen concentrations at 1 m water depth, station 1, Afognak Lake, 2014.

Date	Total filterable-P (µg/L)	Filterable reactive-P (µg/L)	Total-P (µg/L)	Reactive silicon (µg/L)	Ammonia (µg/L)	Total kjeldahl nitrogen (µg/L)	Nitrate + nitrite (µg/L)	Total nitrogen (µg/L)	TN:TP ratio
14-May	0.9	0.7	3.6	1,738.3	1.5	152.0	45.8	197.8	121.7
19-Jun	1.1	0.7	3.4	2,850.9	16.3	1,147.0	5.4	1,152.4	750.5
14-Jul	1.6	1.4	3.9	2,691.0	2.3	289.0	0.1	289.1	164.1
19-Aug	0.9	0.9	3.3	1,810.6	3.1	533.0	6.5	539.5	362.0
15-Sep	1.6	2.3	4.7	2,470.5	4.9	501.0	9.6	510.6	240.6
Average	1.2	1.2	3.8	2,312.3	5.6	524.4	13.5	537.9	327.8
SD	0.4	0.7	0.6	509.8	6.1	381.6	18.4	372.8	253.3

Table 12.–Seasonal average zooplankton abundances (number/m^2) from Afognak Lake, 2014.

Taxon	Date 14-May	19-Jun	14-Jul	19-Aug	15-Sep	Seasonal average
Cladocerans:						
Bosmina	1,460	82,670	96,603	96,072	66,348	68,631
Ovig. *Bosmina*	1,990	5,839	2,123	12,208	4,246	5,281
Ovig. *Chydorinae*	-	-	-	265	-	53
Daphnia l.	398	1,990	7,431	11,412	8,227	5,892
Ovig. *Daphnia l.*	133	398	-	796	1,592	584
Holopedium	398	1,194	3,716	531	-	1,168
Immature Cladocera	1,592	3,716	5,839	4,777	6,104	4,406
Total Cladocerans:	5,971	95,807	115,711	126,062	86,518	86,014
Copepods:						
Cyclops	2,919	1,062	1,858	1,062	1,327	1,645
Ovig. *Cyclops*	-	-	-	265	-	53
Diaptomus	-	1,725	-	531	-	451
Epischura	1,327	7,431	51,752	12,739	2,919	15,234
Ovig. *Epischura*	-	265	-	2,919	3,450	1,327
Harpaticus	-	-	-	1,592	1,327	584
Nauplii	22,028	4,114	4,512	2,389	-	6,608
Total Copepods:	26,274	14,597	58,121	21,497	9,023	25,902
Total Cladocerans + Copepods	32,245	110,403	173,832	147,558	95,541	111,916

Table 13.–Seasonal average zooplankton biomasses (mg/m^2) from Afognak Lake, 2014.

Taxon	14-May	19-Jun	14-Jul	19-Aug	15-Sep	Seasonal average	Seasonal weighted average
Cladocerans:							
Bosmina	1.0	63.2	68.5	67.2	46.5	49.3	48.4
Ovig. *Bosmina*	2.3	6.6	1.8	13.9	4.6	5.8	5.7
Ovig. *Chydorinae*	-	-	-	0.8	-	0.2	0.2
Daphnia l.	0.4	4.1	5.0	13.9	9.6	6.6	6.0
Ovig. *Daphnia l.*	0.2	-	-	1.9	4.0	1.2	1.0
Holopedium	0.6	1.7	9.6	1.9	-	2.8	2.4
Total Cladocerans:	4.5	75.6	84.9	99.6	64.7	65.9	63.7
Copepods:							
Cyclops	3.0	3.4	7.5	1.9	2.9	3.7	3.3
Ovig. *Cyclops*	-	-	-	1.2	-	0.2	0.2
Diaptomus	-	5.7	-	3.8	-	1.9	1.8
Epischura	1.4	40.6	167.1	52.1	13.3	54.9	54.6
Ovig. *Epischura*	-	-	-	28.8	36.4	13.0	12.0
Harpaticus	-	-	-	1.9	1.7	0.7	0.7
Total Copepods:	4.4	49.7	174.6	89.7	54.3	74.5	72.6
Total Cladocerans + Copepods	8.9	125.3	259.5	189.3	119.0	140.4	136.3

Note: Immature species that too small to measure to generate a biomass estimate.

Table 14.–Seasonal averages of zooplankton lengths (mm) from Afognak Lake, 2014.

Taxon	Date					Seasonal average length	Weighted average length
	14-May	19-Jun	14-Jul	19-Aug	15-Sep		
Cladocerans:							
Bosmina	0.29	0.29	0.28	0.27	0.28	0.28	0.28
Ovig. *Bosmina*	0.35	0.35	0.31	0.35	0.34	0.34	0.34
Ovig. *Chydorinae*	-	-	-	0.57	-	0.57	0.57
Daphnia l.	0.47	0.57	0.41	0.52	0.53	0.50	0.50
Ovig. *Daphnia l.*	0.60	-	-	0.74	0.75	0.70	0.64
Holopedium	0.42	0.43	0.51	0.61	-	0.49	0.49
Copepods:							
Cyclops	0.54	0.94	1.06	0.72	0.69	0.79	0.76
Ovig. *Cyclops*	-	-	-	1.12	-	1.12	1.12
Diaptomus	-	0.90	-	1.20	-	1.05	0.97
Epischura	0.61	1.06	0.91	0.93	0.98	0.90	0.92
Ovig. *Epischura*	-	-	-	1.32	1.34	1.33	1.28
Harpaticus	-	-	-	0.61	0.61	0.61	0.61

Table 15.–Relative monthly phytoplankton and mean biovolume in Afognak Lake, by phylum, 2014.

		Phylum							
		Chlorophyta (green algae)	Chrysophyta (golden-brown algae)	Bacillariophyta (diatoms)	Cryptophyta (crytomonads)	Pyrrhophyta (dinoflagellate)	Haptophyta	Cyanobacteria (blue-green algae)	Total
Date	Station	Biovolume (μm^3/L)							
14-May	1	56,622,291	62,331,343	93,709,732	0	40,048,895	0	0	252,712,261
		22.4%	24.7%	37.1%	-	15.8%	-	-	
19-Jun	1	14,378,026	8,393,765	207,351,823	26,918,206	824,051	0	5,802,151	263,668,022
		5.5%	3.2%	78.6%	10.2%	0.3%	-	2.2%	
14-Jul	1	19,168,552	24,108,663	145,491,441	14,049,062	167,088,272	0	3,190,655	373,096,645
		-	6.5%	39.0%	3.8%	44.8%	-	0.9%	
19-Aug	1	5,941,359	0	68,574,882	8,477,670	84,910,239	0	2,703	167,906,853
		3.5%	-	40.8%	5.0%	50.6%	-	0.0%	
15-Sep	1	25,689,482	3,618,315	350,016,759	60,512,006	118,887,326	0	7,827,133	566,551,021
		4.5%	0.6%	61.8%	10.7%	21.0%	-	1.4%	
Mean		24,359,942	19,690,417	173,028,927	21,991,389	82,351,757	0	3,364,528	324,786,960
Mean %		9.0%	8.7%	51.5%	7.4%	26.5%	-	1.1%	

Table 16.–Dates the Afognak Weir was installed and removed by year, 1990-2014.

	Weir		
Year	Installed	Removed	Total days
1990	5/27	9/17	261
1991	5/24	9/8	252
1992	5/24	9/15	259
1993	5/23	9/12	256
1994	5/28	9/18	262
1995	5/29	9/12	256
1996	5/23	9/11	255
1997	5/21	9/13	257
1998	5/20	9/9	253
1999	5/24	9/12	256
2000	5/23	9/11	255
2001	5/26	9/7	251
2002	5/28	8/25	238
2003	5/15	8/23	236
2004	5/15	8/6	219
2005	5/15	8/19	232
2006	5/21	8/4	217
2007	5/21	8/17	230
2008	5/23	8/8	221
2009	5/20	8/6	219
2010	5/19	9/7	251
2011	5/17	8/20	233
2012	5/23	8/25	238
2013	5/23	8/27	240
2014	5/11	8/23	219
Average (1990–2001)			256 (12 Sept)
Average (2004–2014)			229 (17 Aug)

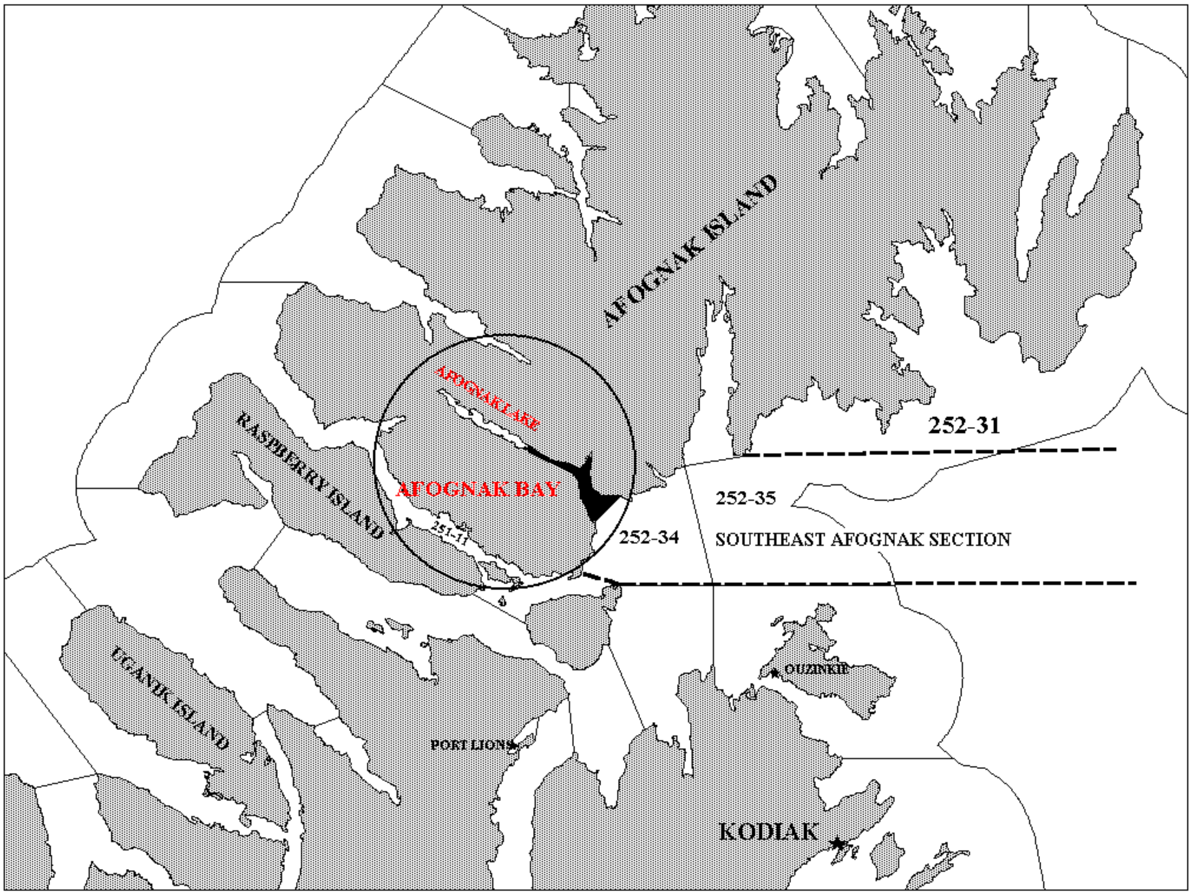

Figure 1.–Map depicting the location of the city of Kodiak, the villages of Port Lions and Ouzinkie, and their proximity to the Afognak Lake drainage on Afognak Island.

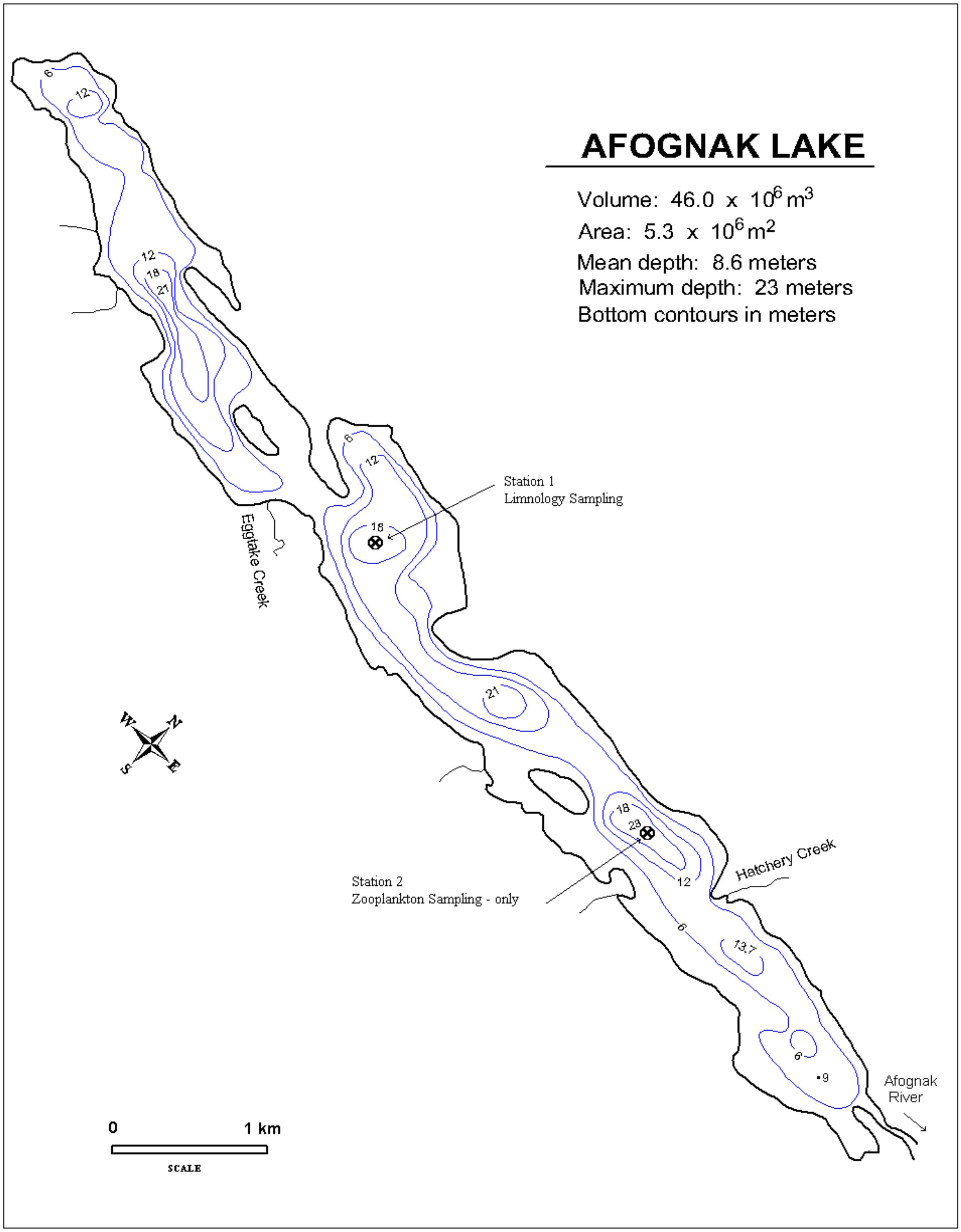

Figure 2.–Bathymetric map showing the limnology and zooplankton sampling stations on Afognak Lake.

Figure 3.–Upstream view of the juvenile sockeye salmon trapping system, 2014.

Figure 4.–View of the adult salmon enumeration weir in Afognak River, 2014.

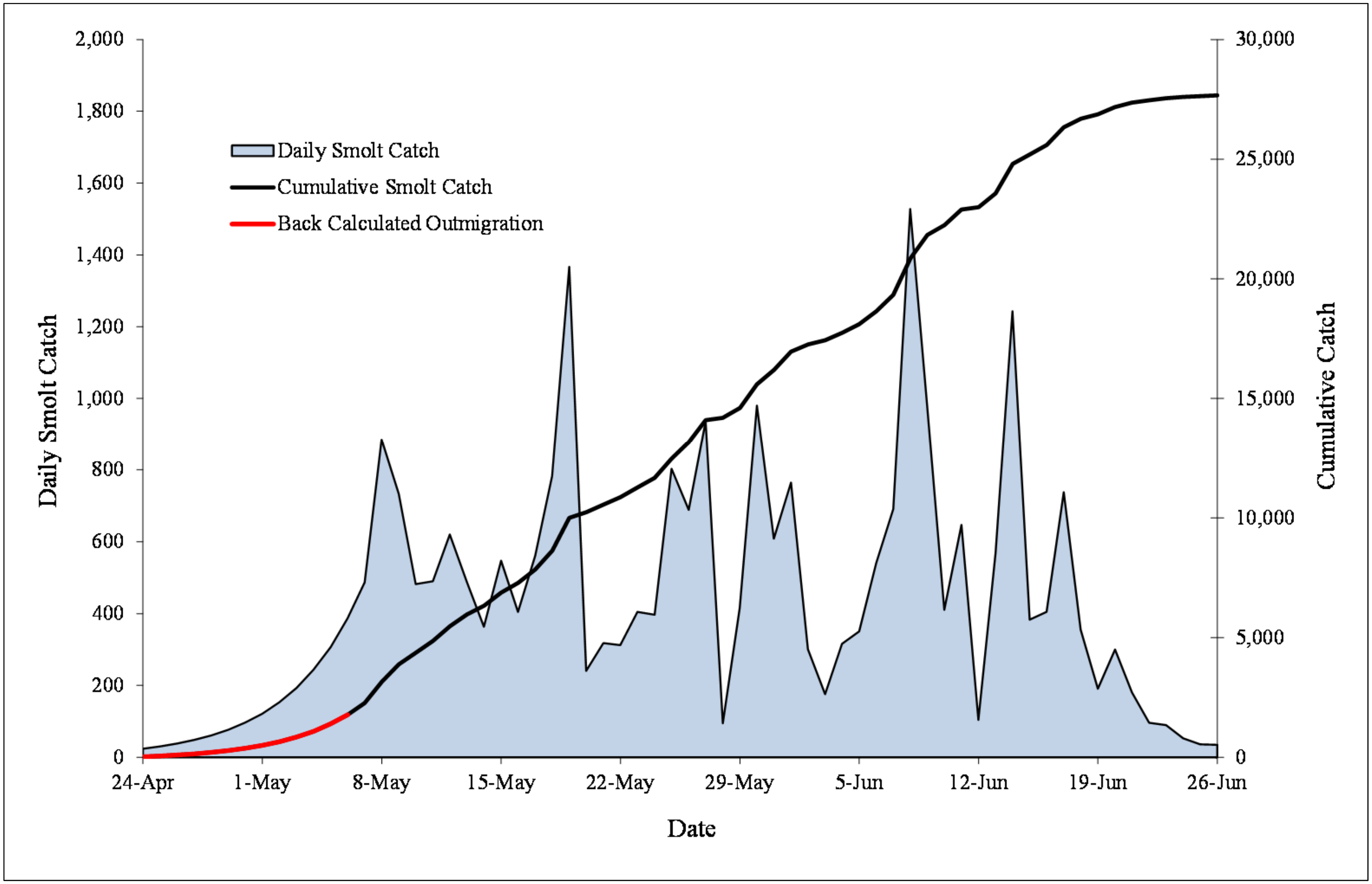

Figure 5.–Daily and cumulative sockeye salmon smolt trap catch from 7 May to 26 June, with prior time series estimates (24 April to 6 May), in the Afognak River, 2014.

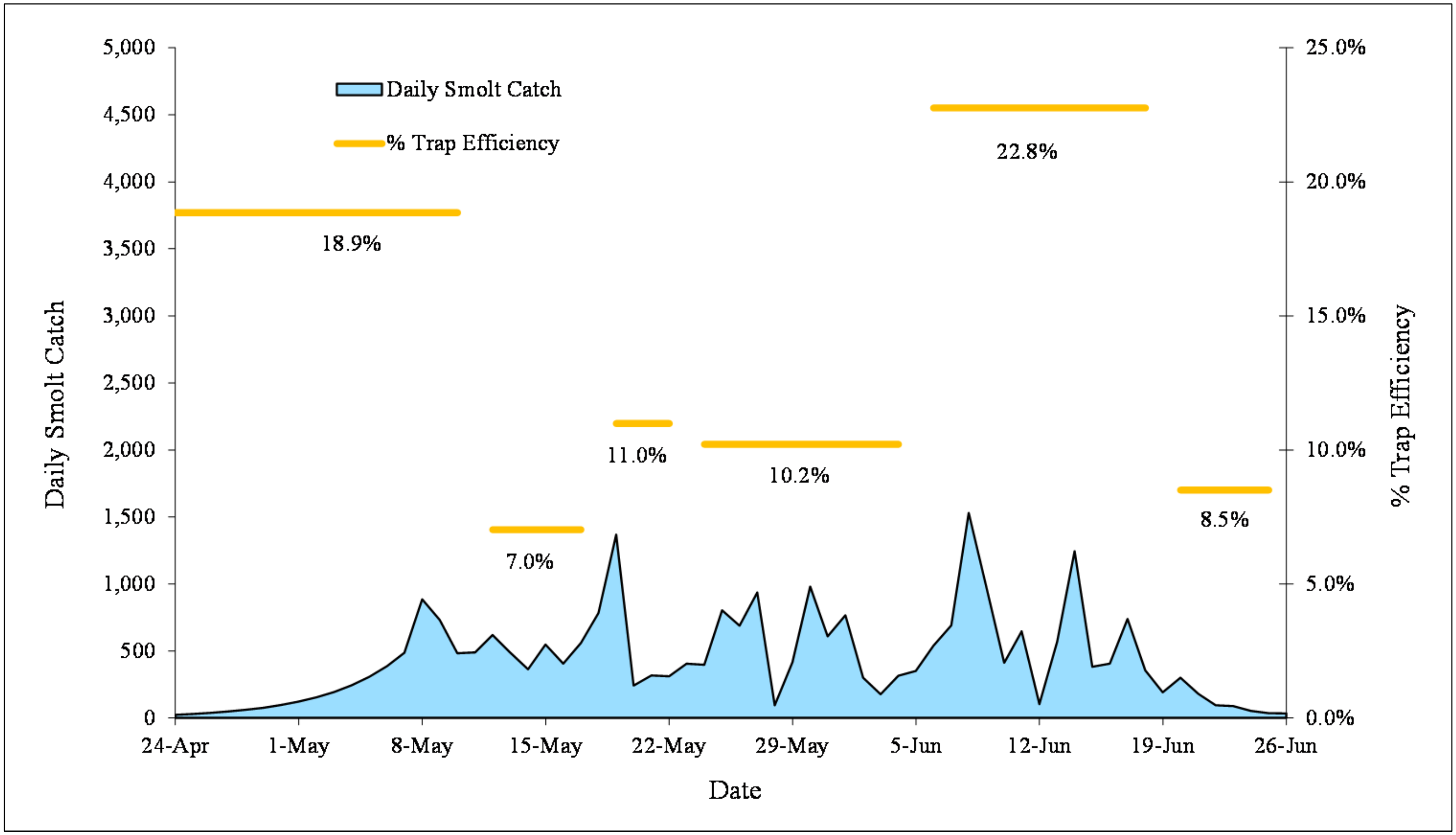

Figure 6.–Daily sockeye salmon smolt trap catch and trap efficiency estimates by strata from 7 May to 26 June in the Afognak River, 2014.

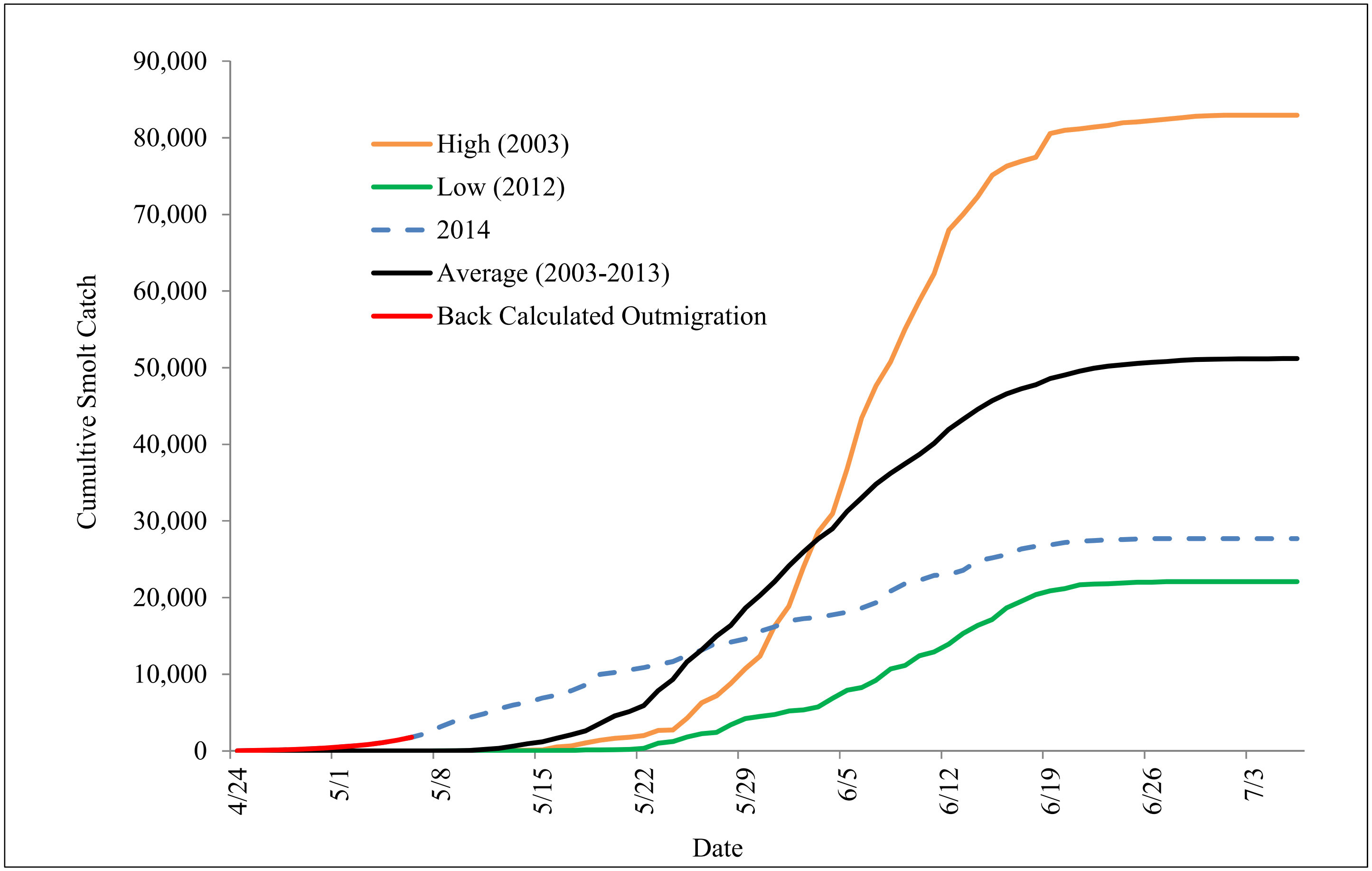

Figure 7.–Cumulative sockeye salmon smolt trap catch in the Afognak River, 2003–2014.

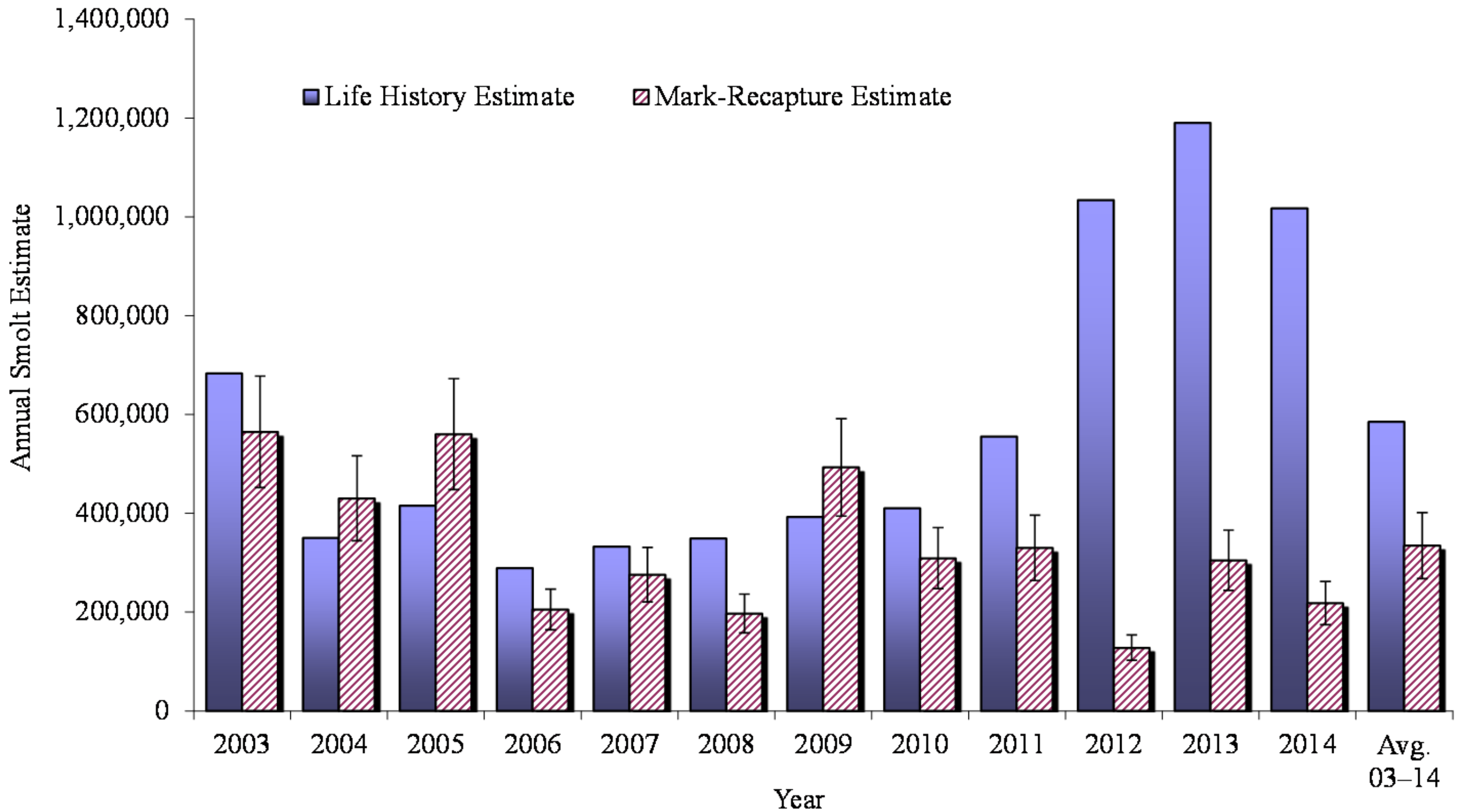

Figure 8.–Comparison of sockeye salmon smolt abundance estimates from life history and mark-recapture models, 2003–2014.

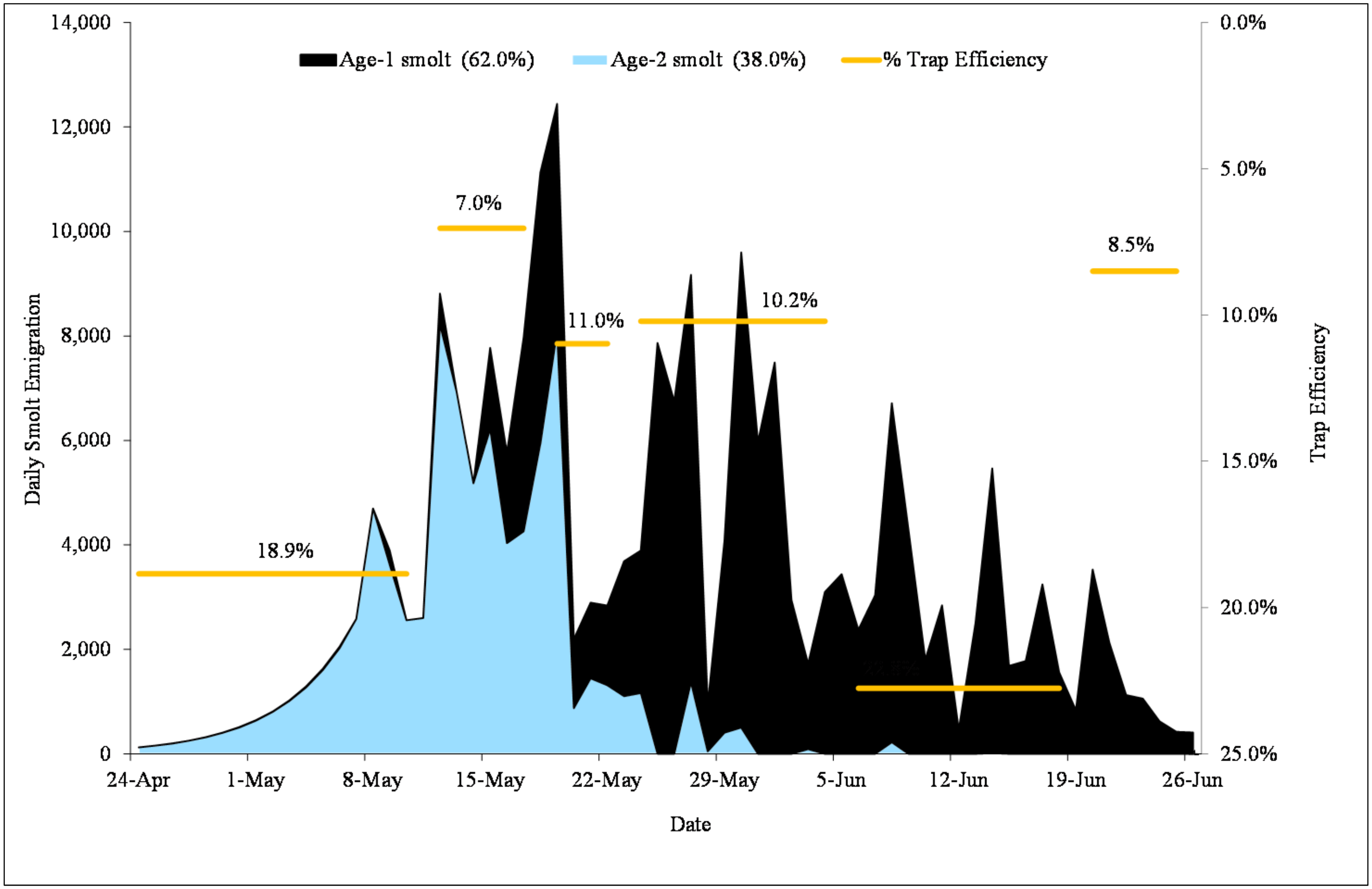

Figure 9.–Afognak Lake sockeye salmon smolt daily outmigration estimates by age class, 2014.

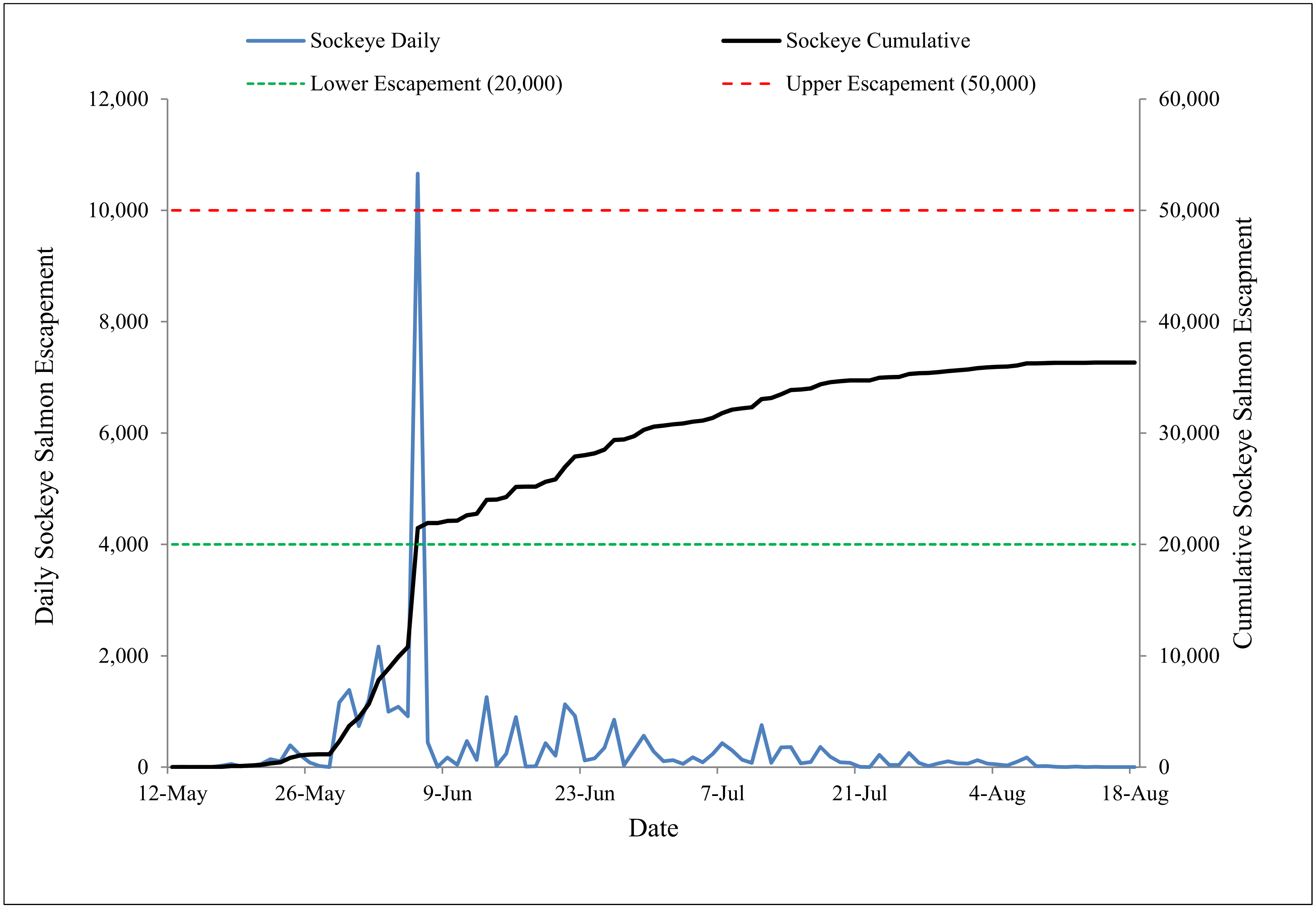

Figure 10.–Afognak Lake adult sockeye salmon daily and cumulative escapement, 2014.

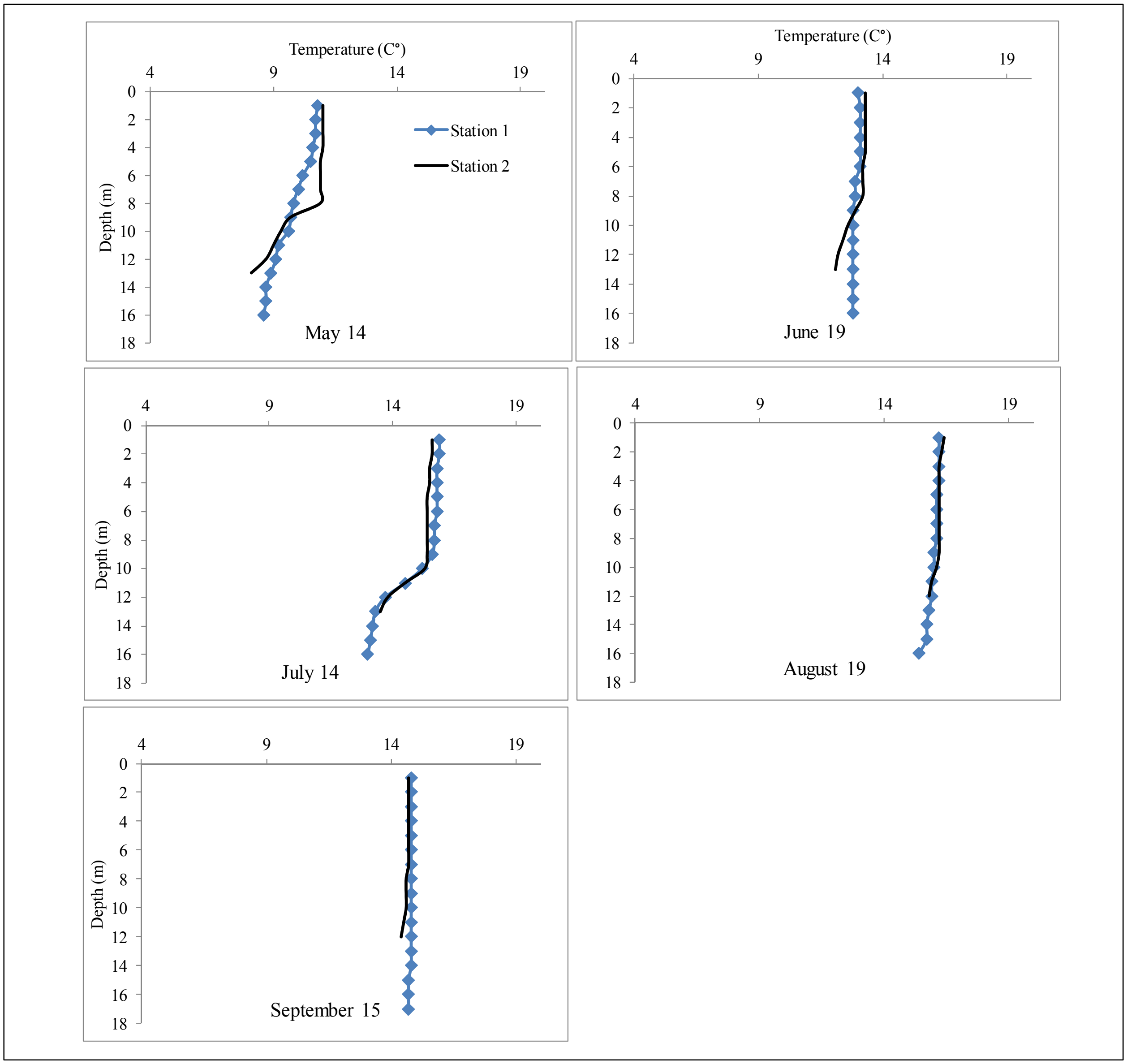

Figure 11.–Temperature profiles by station, by sampling date from Afognak Lake, 2014.

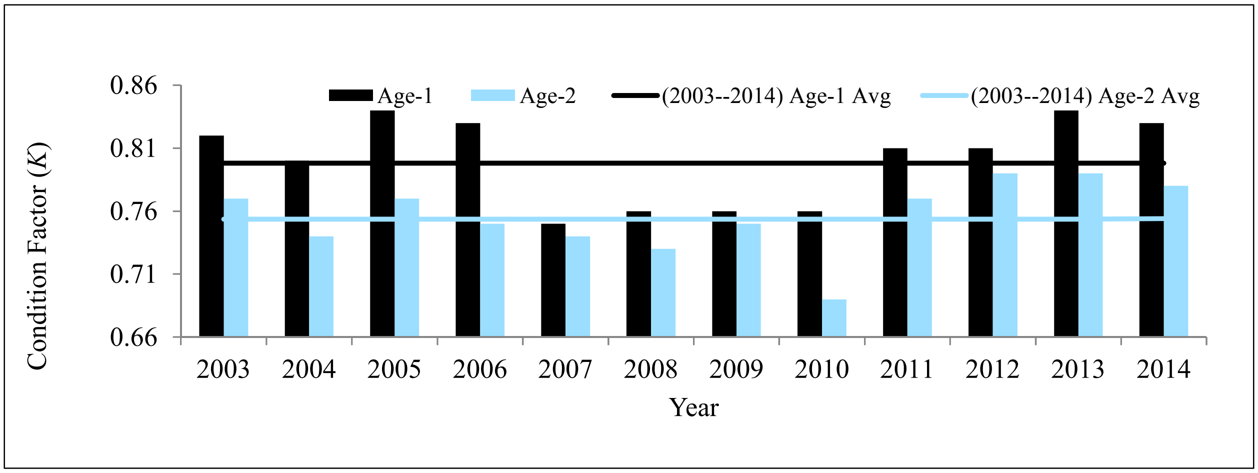

Figure 12.–Relative condition (*K*) of Afognak Lake smolt by year and age, 2003–2014.

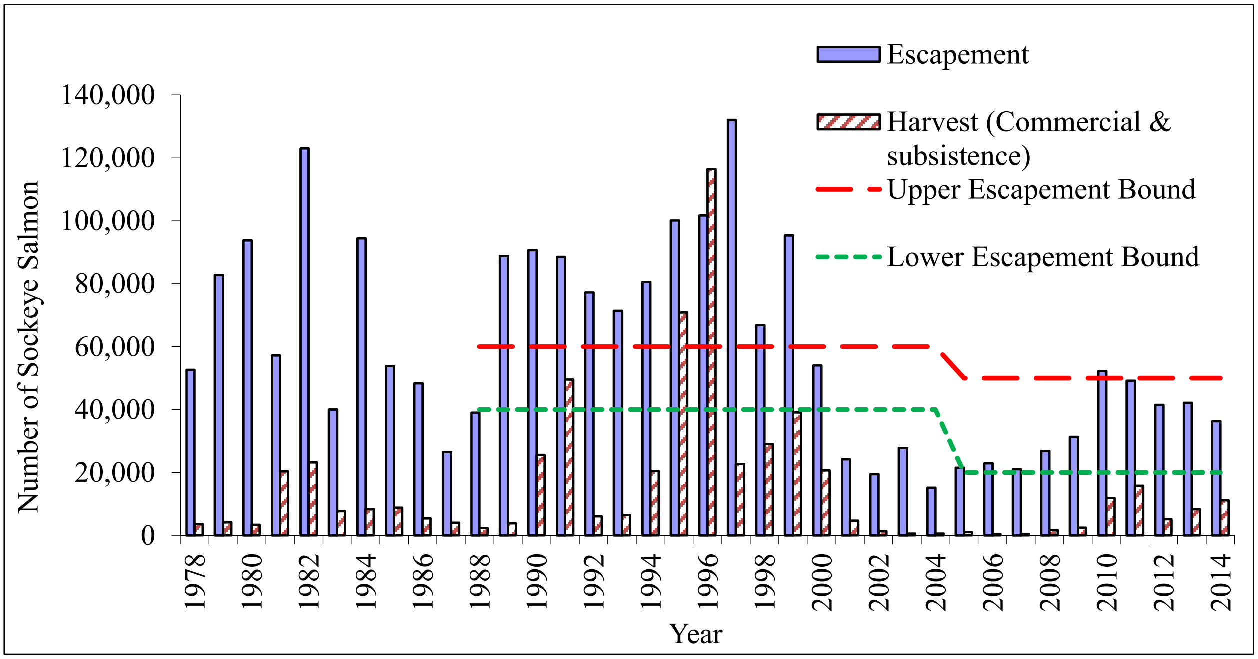

Figure 13.–Escapement and harvest of Afognak Lake sockeye salmon, 1978–2014.

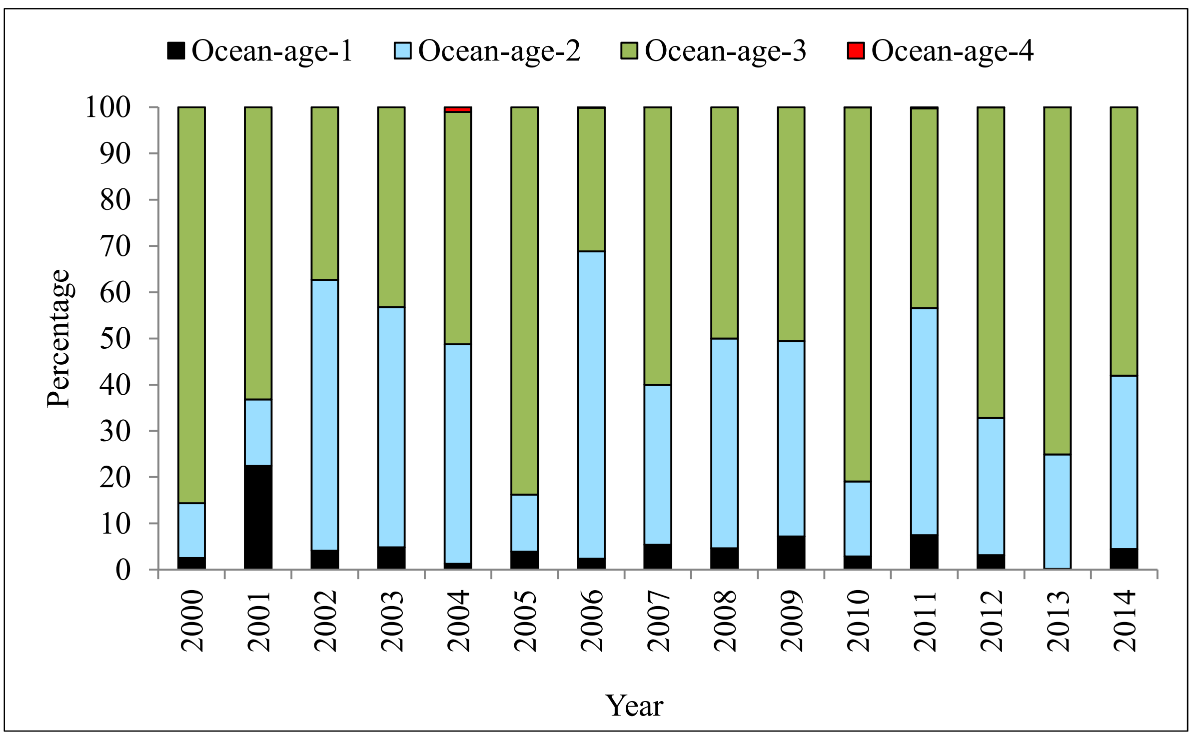

Figure 14.–Percentage of sockeye salmon escapement into Afognak Lake, by ocean age, and year, 2000–2014.

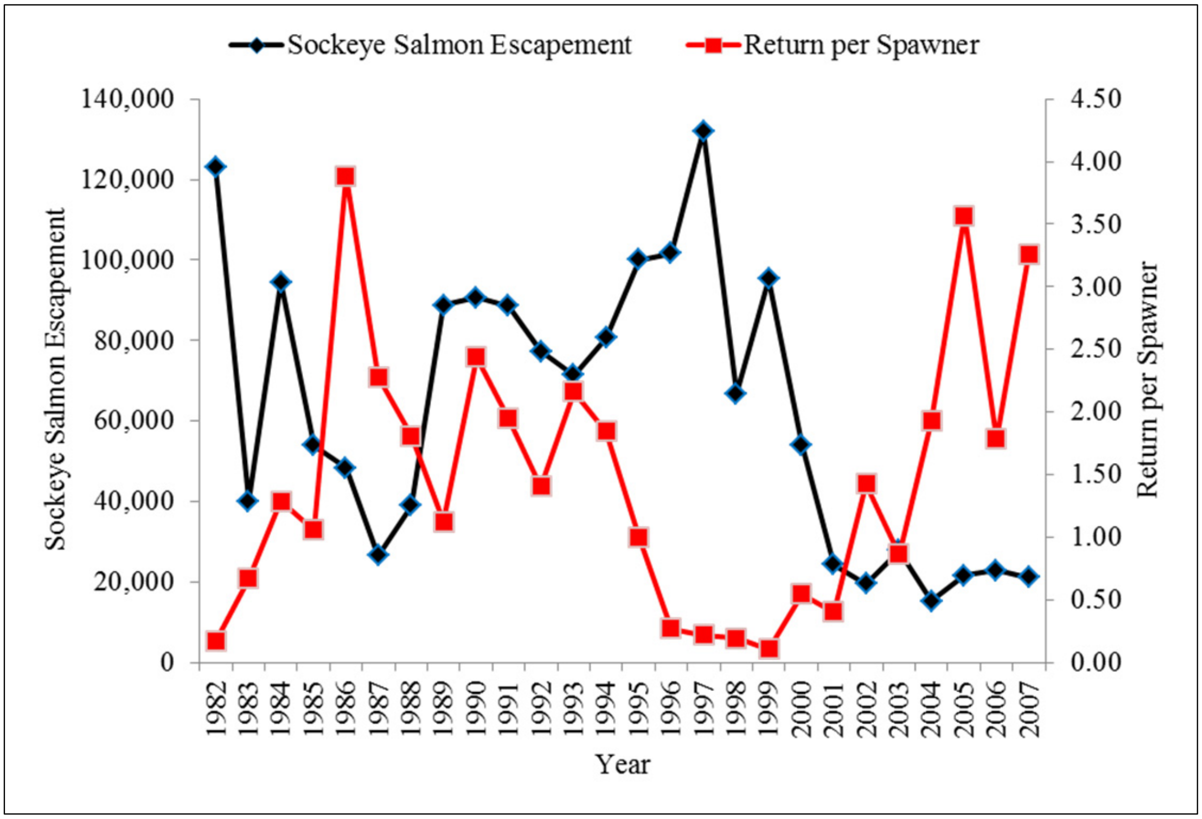

Figure 15.–Relationship between sockeye salmon escapement into Afognak Lake and return per spawner, 1982–2007.

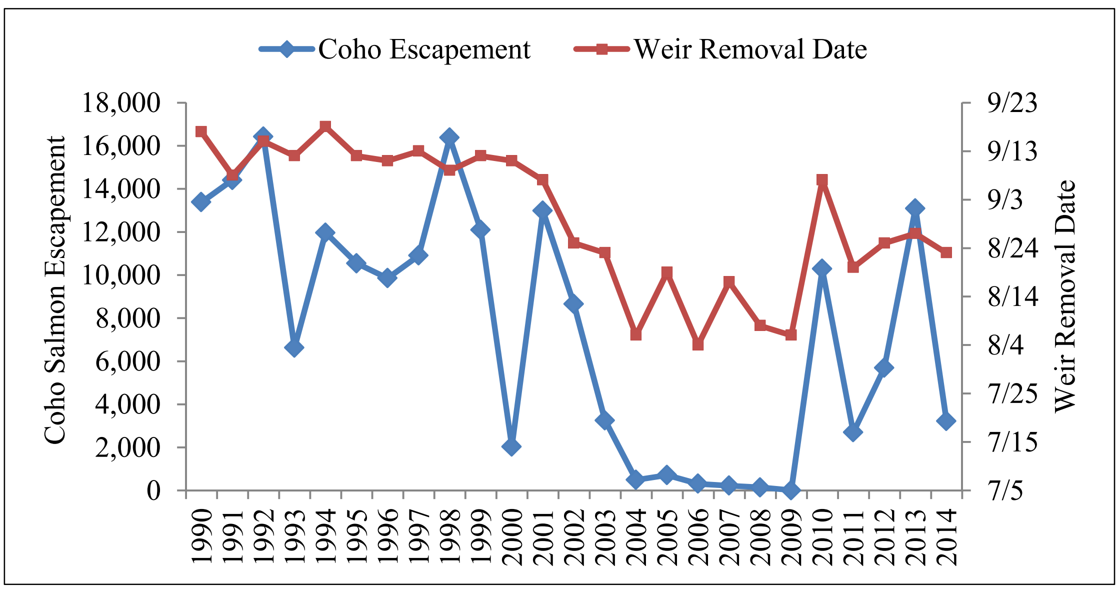

Figure 16.–Afognak Weir removal date compared to coho escapement by year, 1990–2014.

APPENDIX A. SUPPORTING HISTORICAL INFORMATION

Appendix A1.–Population estimates of sockeye salmon smolt outmigrations from Afognak Lake 2003–2014.

Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average trap efficiency (%)	Estimate (U_h)	Variance (U_h)	95% confidence interval Lower	Upper
					2003					
1	5/12	5/19	1,387	239	5	2.1%	55,480	430,580,280	14,809	96,151
2	5/20	5/25	2,912	239	5	2.1%	116,480	1,893,665,280	31,188	201,772
3	5/26	5/31	11,966	706	161	22.8%	52,222	13,071,832	45,136	59,308
4	6/1	6/7	31,358	638	133	20.8%	149,536	131,461,163	127,063	172,008
5	6/8	6/10	11,153	686	257	37.5%	29,698	2,175,656	26,807	32,589
6	6/11	6/18	18,696	679	103	15.2%	122,243	121,222,146	100,663	143,823
7	6/19	6/26	4,762	506	79	15.6%	30,179	9,629,085	24,097	36,261
8	6/27	7/3	736	218	17	7.8%	8,955	3,968,174	5,050	12,859
Total			82,970	3,911	760	19.9%	564,793	2,605,773,616	374,814	754,772
								SE = 51,047		
					2004					
1	5/11	5/26	24,278	525	56	10.7%	224,039	773,437,348	169,530	278,548
2	5/27	6/3	17,727	547	96	17.6%	100,148	84,689,189	82,111	118,186
3	6/4	6/11	16,658	700	211	30.1%	55,081	10,062,676	48,864	61,299
4	6/12	6/19	5,086	613	119	19.4%	26,023	4,609,226	21,815	30,231
5	6/20	7/3	3,779	581	88	15.1%	24,712	5,883,161	19,958	29,466
Total			67,528	2,966	570	18.6%	430,004	878,681,600	371,905	488,104
								SE = 29,643		

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Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average trap efficiency (%)	Estimate (U_h)	Variance (U_h)	95% confidence interval Lower	Upper
					2005					
1	5/10	5/21	27,226	489	70	14.3%	184,879	404,815,551	145,443	224,314
2	5/22	5/26	13,627	518	43	8.3%	155,259	488,664,939	111,932	198,587
3	5/27	6/5	15,210	482	44	9.1%	158,499	493,724,194	114,948	202,050
4	6/6	6/27	17,634	368	103	28.0%	61,593	25,786,901	51,640	71,546
Total			73,697	1,857	260	14.9%	560,230	1,412,991,585	486,554	633,906
								SE = 37,590		
					2006					
1	5/16	6/1	25,983	312	73	23.6%	110,017	123,618,701	88,224	131,809
2	6/2	6/6	8,199	515	98	19.2%	42,726	14,930,053	35,153	50,299
3	6/7	6/16	7,108	485	95	19.8%	35,975	10,850,929	29,519	42,432
4	6/17	6/29	2,534	492	75	15.4%	16,435	3,056,035	13,009	19,861
Total			43,824	1,804	341	19.5%	205,153	152,455,718	180,952	229,353
								SE = 12,347		
					2007					
1	5/10	6/5	14,450	415	51	12.5%	115,690	221,784,590	86,501	144,879
2	6/6	6/12	19,469	202	124	61.5%	31,680	3,089,891	28,235	35,125
3	6/13	6/20	15,281	510	82	16.2%	94,135	88,847,348	75,660	112,609
4	6/21	6/27	5,216	541	108	20.1%	25,914	4,978,154	21,541	30,288
5	6/28	7/4	899	401	44	11.2%	8,031	1,307,504	5,790	10,272
Total			55,315	2,070	409	19.9%	275,450	320,007,488	240,388	310,512
								SE = 17,889		

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Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average trap efficiency (%)	Estimate (U_h)	Variance (U_h)	95% confidence interval Lower	Upper
					2008					
1	5/16	5/31	6,516	202	44	21.2%	29,434	14,766,057	21,903	36,966
2	6/1	6/11	12,500	394	32	8.4%	149,621	605,011,907	101,411	197,831
3	6/12	6/19	2,559	244	53	22.0%	11,989	2,079,787	9,162	14,815
4	6/20	7/3	1,290	306	62	20.5%	5,896	454,235	4,575	7,217
Total			22,865	1,147	191	18.3%	196,941	622,311,987	148,046	245,835
								SE = 24,946		
					2009					
1	5/10	5/22	14,338	381	65	17.3%	82,891	85,202,787	64,799	100,983
2	5/23	6/1	37,537	356	50	14.3%	262,568	1,137,808,443	196,454	328,681
3	6/2	6/9	5,829	420	43	10.5%	55,727	62,257,984	40,261	71,192
4	6/10	6/21	5,753	425	35	8.5%	68,080	115,400,599	47,025	89,136
5	6/22	7/3	1,510	93	5	6.4%	23,732	75,639,388	6,686	40,778
Total			64,967	1,674	198	11.4%	492,998	1,476,309,201	417,689	568,306
								SE = 38,423		
					2010					
1	5/9	5/17	1,026	150	10	7.3%	14,090	15,502,483	6,373	21,807
2	5/18	5/24	788	385	28	7.5%	10,489	3,516,305	6,813	14,164
3	5/25	5/31	17,620	274	39	14.6%	120,961	305,577,452	86,699	155,224
4	6/1	6/7	10,687	275	50	18.5%	57,852	52,723,880	43,620	72,084
5	6/8	6/14	8,802	228	36	16.2%	54,477	65,755,815	38,584	70,371
6	6/15	6/21	2,566	464	27	6.0%	42,585	59,405,936	27,478	57,691
7	6/22	7/1	1,172	488	65	13.5%	8,677	1,026,613	6,691	10,663
Total			42,661	2,263	255	11.9%	309,130	443,075,935	267,874	350,387
								SE = 21,049		

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Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average trap efficiency (%)	Estimate (U_h)	Variance (U_h)	95% confidence interval Lower	Upper
					2011					
1	5/9	6/5	29,701	511	84	16.6%	178,755	311,317,921	144,206	213,303
2	6/6	6/13	10,539	200	35	17.9%	58,843	77,082,015	41,635	76,051
3	6/14	6/20	9,567	462	70	15.3%	62,442	46,195,379	49,120	75,763
4	6/21	6/27	3,628	169	27	16.5%	21,979	14,015,319	14,641	29,317
5	6/28	7/6	974	300	36	12.3%	7,930	1,506,726	5,524	10,336
Total			54,409	1,642	252	15.7%	329,949	450,117,359	288,393	371,502
								SE = 21,201		
					2012					
1	5/8	6/1	5,197	350	69	20.0%	26,037	7,745,327	20,583	31,492
2	6/2	6/7	4,010	314	43	14.0%	28,744	15,972,827	20,911	36,578
3	6/8	6/15	7,933	347	78	22.7%	34,988	11,950,503	28,213	41,764
4	6/16	6/23	4,672	438	55	12.8%	36,632	20,785,598	27,696	45,568
5	6/24	6/28	280	463	88	19.2%	1,460	25,218	1,149	1,771
Total			22,092	1,913	333	17.7%	127,862	56,479,474	98,551	157,173
								SE = 7,515		
					2013					
1	5/8	5/26	10,123	201	38	19.3%	52,432	55,672,176	37,808	67,056
2	5/27	6/2	9,250	582	107	18.5%	49,933	18,854,409	41,422	58,444
3	6/3	6/10	8,167	282	22	8.1%	100,518	387,878,482	61,917	139,119
4	6/11	6/18	7,947	507	48	9.6%	82,438	123,574,935	60,650	104,226
5	6/19	6/27	1,419	319	22	7.2%	19,712	15,267,794	12,053	27,370
Total			36,906	1,891	237	12.6%	305,033	601,247,796	213,849	396,216
								SE = 24,520		

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Appendix A1.–Page 5 of 5.

Stratum (h)	Starting date	Ending date	Catch (u_h)	Released (M_h)	Recaptured (m_h)	Average Trap efficiency (%)	Estimate (U_h)	Variance (U_h)	95% confidence interval Lower	Upper
					2014					
36	18.8%	25,777	4,859	195				14,298,284	18,366	33,189
2	5/12	5/18	3,767	525	36	7.0%	53,565	70,884,179	37,063	70,066
3	5/19	5/23	2,643	527	57	11.0%	24,062	8,927,203	18,206	29,918
4	5/24	6/5	6,834	332	33	10.2%	66,965	115,620,744	45,890	88,040
5	6/6	6/19	8,777	271	61	22.8%	38,566	18,364,650	30,167	46,966
6	6/20	6/26	791	234	19	8.5%	9,304	3,866,804	5,450	13,158
Total			27,671	2,085	242	13.1%	218,239	231,961,865	155,141	281,338
								SE = 15,230		
Average (2003–2014)			49,575			16.1%	334,648			
SD (2003–2014)			20,232			3.3%	146,200			
Average (2010–2014)			36,748			14.2%	258,043			
SD (2010–2014)			12,690			2.4%	84,439			

Appendix A2.–Mean and percentage composition by year of sockeye salmon smolt sampled from outmigrants at Afognak Lake, 2003–2014.

	Age						
Year	1	%	2	%	3	%	Total
2003	373,513	66.1%	191,279	33.9%	0	0.0%	564,793
2004	387,584	90.1%	42,420	9.9%	0	0.0%	430,004
2005	521,025	93.0%	39,205	7.0%	0	0.0%	560,230
2006	146,527	71.4%	58,626	28.6%	0	0.0%	205,153
2007	237,383	86.2%	38,067	13.8%	0	0.0%	275,450
2008	92,018	46.7%	104,923	53.3%	0	0.0%	196,941
2009	427,141	86.6%	64,560	13.1%	1,296	0.3%	492,998
2010	237,716	76.9%	71,415	23.1%	0	0.0%	309,130
2011	250,741	76.0%	79,207	24.0%	0	0.0%	329,948
2012	99,541	77.6%	28,321	22.4%	0	0.0%	127,861
2013	249,107	81.7%	55,630	18.2%	296	0.1%	305,033
2014	135,410	62.0%	82,830	38.0%	0	0.0%	218,239
Mean (2003–2014)	263,142	76.2%	71,373	23.8%	133	0.0%	334,648
Mean (2010–2014)	194,503	74.8%	63,480	25.1%	59	0.0%	258,042

Appendix A3.–Mean weight, length, and condition factor by age for sockeye salmon smolt sampled at Afognak Lake, 1987–2001, and 2003–2014.

		Age-1				Age-2			
Year	Sampling period	Sample size (n)	Weight (g)	Length (mm)	Condition (K)	Sample size (n)	Weight (g)	Length (mm)	Condition (K)
1987	8-Jun	36	3.6	74.9	0.85	186	3.6	79.3	0.86
1988	15-Jun	202	4.1	77.9	0.90	0			
1989	15-Jun	208	4.1	76.8	0.91	2	5.2	78.0	1.10
1990	23 May–24 June	544	2.5	68.8	0.76	21	3.4	77.3	0.73
1991	13 May–26 June	1,895	3.1	72.9	0.78	176	3.9	78.3	0.81
1992	7 June–20 June	268	3.8	77.0	0.82	37	3.8	76.9	0.83
1993	24 May–30 May	274	3.0	72.7	0.78	21	3.3	74.8	0.79
1994	17 May–23 May	138	3.0	72.0	0.81	142	4.7	84.3	0.79
1995	31 May–13 June	394	2.8	69.4	0.84	5	3.6	78.8	0.74
1996	5 June–11 June	54	4.6	80.9	0.87	339	4.8	81.6	0.88
1997	24 May–30 May	76	4.3	81.7	0.78	122	4.4	82.1	0.79
1998	24 May–30 May	116	2.6	66.4	0.82	46	6.6	88.0	0.90
1999	31 May–6 June	96	2.8	74.6	0.66	98	2.1	66.6	0.69
2000	31 May–13 June	84	4.9	81.5	0.89	100	5.6	85.3	0.89
2001	11 June–13 June	44	7.0	90.1	0.93	17	5.8	85.6	0.92
2003	12 May–3 July	1,031	4.2	79.1	0.82	383	4.2	81.4	0.77
2004	11 May–3 July	1,370	3.6	75.7	0.80	81	3.6	78.7	0.74
2005	10 May–27 June	1,248	3.9	76.8	0.84	65	4.2	81.3	0.77
2006	16 May–29 June	765	3.0	70.8	0.83	202	3.8	79.6	0.75
2007	21 May–2 July	960	2.6	70.4	0.75	129	3.4	76.5	0.74
2008	26 May–28 June	169	3.4	75.9	0.76	164	4.0	81.7	0.73
2009	13 May–29 June	1053	3.5	76.7	0.76	205	5.3	88.8	0.75
2010	9 May–1 July	601	2.6	69.9	0.76	198	3.9	82.1	0.69
2011	9 May–6 July	757	3.1	71.8	0.81	128	3.7	78.4	0.77
2012	8 May–28 June	378	3.1	72.5	0.81	134	3.9	79.1	0.78
2013	8 May–27 June	534	3.8	76.6	0.84	220	4.7	84.2	0.79
2014	7 May–26 June	353	3.5	74.0	0.83	160	4.1	80.6	0.78
Average (1987–2013)		511	3.6	75.1	0.81	124	4.2	80.3	0.80
Average (2003–2014)		768	3.4	74.2	0.80	172	4.1	81.0	0.76
Average (2010–2014)		525	3.2	73.0	0.81	168	4.1	80.9	0.76

Appendix A4.–Estimated age composition of the Afognak Lake sockeye salmon escapement, 1985–2014.

Year	Sample size (n)		Ages 1.1	1.2	2.1	1.3	2.2	1.4	2.3	3.2	Total[a]
1985	691	Percent	0.0	26.0	0.0	51.1	14.1	0.4	8.4	0.0	100.0
		Numbers	15	14,027	0	27,506	7,593	206	4,525	0	53,872
1986	484	Percent	0.6	10.1	0.2	74.8	5.8	0.2	8.1	0.0	100.0
		Numbers	300	4,893	100	36,150	2,796	100	3,895	0	48,333
1987	647	Percent	5.2	32.2	1.0	45.3	2.5	0.0	13.8	0.0	100.0
		Numbers	1,376	8,513	257	11,992	660	0	3,645	0	26,474
1988	933	Percent	0.7	59.5	3.2	24.2	11.2	0.0	0.9	0.0	100.0
		Numbers	257	23,227	1,233	9,441	4,363	0	350	0	39,012
1989	543	Percent	8.7	11.4	3.1	50.8	24.1	0.0	1.8	0.0	100.0
		Numbers	7,688	10,142	2,781	45,149	21,429	0	1,636	0	88,825
1990	1,053	Percent	0.7	46.7	0.6	22.6	8.6	0.3	20.5	0.0	100.0
		Numbers	598	42,314	554	20,518	7,754	262	18,614	0	90,666
1991	1,062	Percent	0.3	14.7	0.2	76.6	3.5	0.0	4.6	0.0	100.0
		Numbers	295	13,055	195	67,808	3,099	0	4,105	0	88,557
1992	1,025	Percent	21.2	22.2	9.9	29.9	3.8	0.5	12.3	0.0	100.0
		Numbers	16,360	17,114	7,680	23,096	2,938	394	9,527	0	77,260
1993	852	Percent	16.6	10.7	17.2	30.3	12.3	0.0	12.5	0.2	100.0
		Numbers	11,838	7,634	12,318	21,676	8,815	0	8,965	162	71,460
1994	840	Percent	9.6	30.6	4.1	35.2	10.3	0.1	9.6	0.1	100.0
		Numbers	7,703	24,648	3,337	28,387	8,315	62	7,707	64	80,570
1995	848	Percent	2.3	21.8	0.8	56.3	10.8	0.1	7.8	0.0	100.0
		Numbers	2,282	21,786	838	56,366	10,773	147	7,778	0	100,131
1996	1,119	Percent	16.1	9.2	2.1	44.0	2.1	0.2	26.0	0.1	100.0
		Numbers	16,339	9,398	2,183	44,744	2,094	184	26,428	81	101,718

[a] Totals include some age classes not listed.

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Year	Sample size (n)		Ages 1.1	1.2	2.1	1.3	2.2	1.4	2.3	3.2	Total[a]
1997	1,168	Percent	5.1	25.9	6.6	45.8	2.0	0.0	14.6	0.0	100.0
		Numbers	6,704	34,145	8,697	60,416	2,632	41	19,247	0	132,050
1998	1,240	Percent	19.0	8.0	7.1	49.1	10.6	0.4	5.5	0.0	100.0
		Numbers	12,720	5,371	4,767	32,826	7,099	250	3,684	0	66,869
1999	1,195	Percent	1.1	38.8	0.5	9.5	42.7	0.2	6.6	0.5	100.0
		Numbers	1,030	36,992	506	9,043	40,720	232	6,278	455	95,361
2000	1,161	Percent	2.1	2.5	0.3	15.7	6.0	0.0	69.1	3.3	100.0
		Numbers	1,121	1,348	188	8,484	3,228	0	37,382	1,806	54,064
2001	790	Percent	1.4	11.0	6.2	23.4	3.2	0.0	39.3	0.0	100.0
		Numbers	334	2,681	1,496	5,683	775	0	9,540	0	24,271
2002	238	Percent	0.1	1.0	3.2	32.6	24.7	0.0	4.8	32.8	100.0
		Numbers	19	194	625	6,358	4,830	0	935	6,399	19,520
2003	498	Percent	4.1	22.6	0.2	0.8	25.7	0.0	29.6	2.8	100.0
		Numbers	1,148	6,273	66	233	7,141	0	8,229	770	27,766
2004	566	Percent	1.1	44.3	0.2	19.0	1.8	0.0	26.8	0.0	100.0
		Numbers	170	6,720	25	2,888	280	3	4,073	0	15,181
2005	572	Percent	3.2	10.0	0.6	82.0	2.2	0.0	1.3	0.0	100.0
		Numbers	683	2,153	136	17,697	472	0	280	0	21,577
2006	613	Percent	2.5	63.1	0.0	22.1	2.6	0.0	9.4	0.0	100.0
		Numbers	569	14,481	0	5,075	596	36	2,156	0	22,933
2007	590	Percent	5.1	32.5	0.3	54.4	2.1	0.0	5.6	0.0	100.0
		Numbers	1,076	6,844	67	11,461	436	8	1,178	0	21,070
2008	643	Percent	4.3	41.6	0.3	49.4	3.7	0.0	0.6	0.0	100
		Numbers	1,165	11,177	87	13,269	1,003	0	173	0	26,874

[a] Totals include some age classes not listed.

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Year	Sample size (n)		Ages								
			1.1	1.2	2.1	1.3	2.2	1.4	2.3	3.2	Total[a]
2009	776	Percent	4.5	39.9	2.7	47.7	2.3	0.0	2.8	0.0	100
		Numbers	1,412	12,520	852	14,969	722	0	884	0	31,358
2010	954	Percent	2.6	15.8	0.2	80.6	0.5	0.1	0.2	0.0	100
		Numbers	1,377	8,234	103	42,108	267	52	114	0	52,255
2011	750	Percent	4.2	40.2	3.3	28.5	8.8	0.3	14.7	0.0	100
		Numbers	2,086	19,771	1,606	14,015	4,340	152	7,222	0	49,193
2012	767	Percent	2.3	15.7	0.8	56.7	14.0	0.1	10.4	0.0	100
		Numbers	968	6,531	325	23,565	5,800	48	4,315	0	41,553
2013	747	Percent	0.2	19.6	0.0	63.9	5.1	0.0	11.1	0.0	100
		Numbers	78	8,269	0	26,939	2,169	17	4,682	0	42,153
2014	570	Percent	3.8	23.0	0.7	44.7	14.3	0.0	13.4	0.0	100
		Numbers	1,373	8,365	245	16,230	5,204	0	4,874	0	36,345
Average (1992–2013)		Percent	5.8	23.9	3.0	39.9	9.0	0.1	14.6	1.8	
		Numbers	3,963	12,013	2,086	21,332	5,247	74	7,763	443	53,418
Average (2003–2013)		Percent	3.1	31.4	0.8	45.9	6.3	0.1	10.2	0.3	
		Numbers	976	9,361	297	15,656	2,111	29	3,028	70	31,992
Average (2010–2014)		Percent	2.6	22.9	1.0	54.9	8.5	0.1	10.0	0.0	
		Numbers	1,177	10,234	456	24,572	3,556	54	4,241	0	44,300

[a] Totals include some age classes not listed.

Appendix A5.–Afognak Weir cumulative escapement counts by year and species, 1990–2014.

Year	Sockeye	Chinook	Pink	Coho	Chum	Steelhead down	Steelhead up	All species
1990	90,666	0	27,808	13,380	0	191	61	132,106
1991	88,557	0	13,985	14,409	0	392	24	117,367
1992	77,260	0	28,945	16,415	0	202	34	122,856
1993	71,460	2	21,830	6,637	0	173	44	100,146
1994	80,570	5	49,756	11,965	8	356	11	142,671
1995	100,131	3	42,738	10,542	0	335	46	153,795
1996	101,718	0	11,307	9,856	14	154	103	123,152
1997	132,050	1	19,122	10,908	4	563	8	162,656
1998	66,869	3	101,177	16,374	14	150	78	184,665
1999	95,361	8	30,959	12,092	11	783	31	139,245
2000	54,064	8	67,003	2,036	8	185	18	123,322
2001	24,271	1	25,228	12,981	6	118	4	62,609
2002	19,520	1	76,242	8,654	3	67	0	104,487
2003	27,766	1	34,330	3,256	13	221	1	65,588
2004	15,181	2	9,563	492	40	63	3	25,344
2005	21,577	2	41,594	715	0	59	0	63,947
2006	22,933	4	9,235	312	11	80	0	32,575
2007	21,070	0	11,777	225	9	309	1	33,391
2008	26,874	0	15,716	147	1	316	0	43,054
2009	31,358	0	895	13	6	383	1	32,656
2010	52,255	1	62,237	10,288	59	256	1	125,097
2011	49,193	0	4,241	2,700	4	128	0	56,266
2012	41,553	1	111,928	5,701	5	91	0	159,279
2013	42,153	1	17,400	13,090	1	78	0	64,723
2014	36,345	1	18,408	3,224	0	85	10	58,063
Average Fertilization Yrs. (1990–2001)	81,915	3	36,655	11,466	5	300	39	130,383
Average All Years (1990–2013)	56,434	2	34,792	7,633	9	236	20	98,792
10-year Average (2004–2013)	32,415	1	28,459	3,368	14	176	1	63,633
5-year Average (2010–2014)	44,300	1	42,843	7,001	14	128	2	92,686

Appendix A6.–Temperatures (°C) measured at the 1-meter and near bottom strata at station 1 in the spring (May–June), summer (July–August), and fall (September–October) for Afognak Lake, 1989–2014.

	Spring		Summer		Fall	
Year	Surface	Bottom	Surface	Bottom	Surface	Bottom
1989	7.8	7.0	16.3	12.8	15.3	13.6
1990	9.4	8.3	14.8	13.6	11.9	11.4
1991	6.2	5.7	15.1	12.5	12.4	12.1
1992	10.0	8.9	15.5	13.9	11.1	11.0
1993	11.9	10.4	17.6	14.5	13.5	12.6
1994	10.8	8.8	15.5	13.5	10.2	9.7
1995	8.8	7.3	15.2	12.8	12.5	11.9
1996	11.5	9.7	15.2	13.9	11.1	10.5
1997	10.3	7.5	17.6	10.6	14.1	12.4
1998	7.9	7.7	14.3	13.0	11.8	11.6
1999	7.0	6.2	15.1	11.4	10.4	10.1
2000	9.7	8.7	15.0	13.1	10.1	10.0
2001	9.1	7.0	17.1	10.2	12.9	12.5
2002	10.0	7.8	16.0	10.8	9.3	9.2
2003	9.7	5.5	18.3	12.9	11.5	11.3
2004	9.2	8.2	15.1	11.7	13.1	12.9
2005	11.8	9.5	18.1	13.5	13.6	13.5
2006	9.2	8.0	15.8	12.5	12.6	12.5
2007	9.2	6.7	15.4	10.7	12.4	12.3
2008	8.6	6.9	14.7	13.3	11.9	11.4
2009	11.1	8.4	17.4	13.9	12.4	12.2
2010	8.7	8.1	15.1	14.2	14.9	14.1
2011	8.2	7.4	14.7	12.6	12.1	11.5
2012	10.2	7.6	14.4	12.2	11.8	11.9
2013	11.9	10.7	16.1	14.2	14.8	14.7
2014	11.9	10.7	16.1	13.7	14.8	14.7
Average (1989–2013)	9.5	7.9	15.8	12.7	12.3	11.9
Average (2010–2014)	10.2	8.9	15.3	13.4	13.7	13.4

Appendix A7.–Dissolved oxygen concentrations (mg /L) measured at the 1-meter and near bottom strata at station 1 in the spring (May–June), summer (July–August), and fall (September–October) for Afognak Lake, 1989–2014.

	Spring		Summer		Fall	
Year	Surface	Bottom	Surface	Bottom	Surface	Bottom
1989	11.7	11.2	10.3	9.2	13.1	10.3
1990	14.0	11.8	9.5	8.6	9.6	8.9
1991	12.6	11.1	10.9	8.2	10.5	9.4
1992	11.5	10.8	10.1	8.7	10.8	10.8
1993	10.9	9.8	9.5	7.5	10.5	10.1
1994	11.0	9.8	10.0	8.1	11.3	10.9
1995	11.4	11.3	10.0	8.4	10.5	9.8
1996	10.9	10.5	10.0	7.7	11.2	11.1
1997	10.5	10.7	9.0	4.6	10.2	7.6
1998	11.8	11.7	10.2	6.1	10.2	10.0
1999	11.9	11.5	9.6	6.2	10.9	10.4
2000	11.0	9.1	9.7	6.8	10.5	10.1
2001	9.7	9.6	9.3	4.7	9.0	8.1
2002	10.8	9.3	9.8	3.9	10.5	10.1
2003	12.0	11.1	9.2	5.5	18.0	10.3
2004	12.9	11.2	11.5	8.1	10.5	6.4
2005	10.8	10.2	9.5	5.1	9.5	8.7
2006	10.9	10.0	9.8	8.3	10.5	10.0
2007	11.4	10.8	9.2	6.6	10.6	9.9
2008	12.5	10.7	9.5	8.9	9.5	9.9
2009	10.9	10.3	9.0	7.9	8.9	8.6
2010	10.8	9.8	9.7	8.8	10.2	9.8
2011	12.2	11.9	10.2	8.4	10.2	9.9
2012	12.1	11.8	10.7	9.7	11.0	10.6
2013	12.2	11.9	9.9	7.6	10.0	9.7
2014	10.9	10.5	8.9	6.5	8.9	8.6
Average (1989–2013)	11.5	10.7	9.8	7.2	10.7	9.6
Average (2010–2014)	11.6	11.2	9.9	8.2	10.1	9.7

Appendix A8.–Average euphotic zone depth (EZD), light extinction coefficient (K_d), Secchi disk transparency, and euphotic volume (EV) for Afognak Lake, 1989–2014.

Year	EZD (m)	SD	K_d (m^{-1})	SD	Secchi (m)	SD	EV ($10^6 m^3$)	SD
1987	8.43	1.14	NA	NA	4.7	1.4	44.65	6.04
1988	11.91	2.78	NA	NA	4.2	0.5	63.14	14.73
1989	13.05	3.53	-0.39	0.08	4.75	0.28	69.16	18.68
1990	9.31	3.04	-0.55	0.25	3.64	0.63	49.35	16.12
1991	10.41	3.10	-0.49	0.18	2.76	0.39	55.19	16.44
1992	10.54	2.15	-0.45	0.08	2.80	0.92	55.87	11.39
1993	9.40	3.13	-0.58	0.31	3.51	0.53	49.82	16.60
1994	7.40	1.51	-0.61	0.11	3.39	0.35	39.23	8.03
1995	7.39	1.33	-0.61	0.12	2.45	0.54	39.17	7.06
1996	7.95	1.69	-0.58	0.14	3.52	0.41	42.14	8.97
1997	8.47	1.32	-0.56	0.12	3.24	0.74	44.90	7.00
1998	7.36	0.95	-0.60	0.09	3.75	1.21	39.01	5.01
1999	8.93	2.79	-0.56	0.11	2.94	0.55	47.31	14.79
2000	9.81	1.60	-0.46	0.07	3.38	0.67	52.00	8.48
2001	11.04	3.35	-0.46	0.12	3.95	1.14	58.50	17.75
2002	10.51	0.57	-0.41	0.02	4.25	0.54	55.72	3.03
2003	9.80	1.31	-0.44	0.06	4.50	0.23	51.92	6.94
2004	10.19	2.99	-0.46	0.08	4.10	0.49	54.00	15.86
2005	9.55	0.71	-0.46	0.05	4.83	0.63	50.63	3.77
2006	9.03	1.01	-0.49	0.07	4.04	0.71	47.87	5.35
2007	9.44	1.17	-0.49	0.08	4.10	0.66	50.05	6.22
2008	9.07	1.47	-0.51	0.08	4.33	0.35	48.06	7.82
2009	9.36	0.41	-0.48	0.03	4.40	0.72	49.63	2.19
2010	10.03	1.29	-0.44	0.06	4.50	0.80	53.13	6.83
2011	8.14	1.09	-0.55	0.08	4.25	0.59	43.16	5.77
2012	9.73	0.51	-0.45	0.03	4.98	0.45	51.56	2.69
2013	8.67	0.96	-0.52	0.06	4.75	0.60	45.96	5.09
2014	7.87	0.75	-0.56	0.06	4.15	0.44	41.74	3.99
Average (1987–2013)	9.44	1.74	-0.50	0.10	3.92	0.63	50.04	9.21
Average (2010–2014)	8.89	0.92	-0.51	0.06	4.53	0.58	47.11	4.87

Note: Values are updated to reflect current database calculations (Heather Finkle, ADF&G, Personal Communication). SD = standard deviation.

Appendix A9.–Summary of seasonal mean water chemistry parameters by station and depth for Afognak Lake, 1987–2014.

Year	Station	Depth (m)	Sp. conductivity (µmhos cm)	SD	pH (Units)	SD	Alkalinity (mg/L)	SD	Turbidity (NTU)	SD	Color (Pt units)	SD	Calcium (mg/L)	SD	Magnesium (mg/L)	SD	Iron (µg/L)	SD
1987	1	1	47	2.6	6.7	0.2	10.0	0.8	0.8	0.3	8	1.7	3.6	0	0.6	0	76	34.9
	1	17	46	2.8	6.7	0.4	9.5	1.0	0.7	0.4	8	2.6	4	0	1	0	58	17.3
1988	1	1	51	5.9	6.7	0.5	10.8	1.3	1.4	1.0	12	2.4	4.7	ND	1.6	ND	50	13.6
	1	15	50	0.5	6.9	0.2	11.3	1.0	1.1	0.8	10	1.3	ND	ND	ND	ND	81	77.7
	2	1	51	3.7	6.9	0.1	10.5	1.7	1.4	1.1	12	3.2	ND	ND	ND	ND	63	22.3
	2	10	50	2.3	6.8	0.1	10.3	0.6	1.5	1.2	9	2.9	ND	ND	ND	ND	96	52.7
1989	1	1	64	1.9	7.0	0.5	10.6	1.5	2.4	3.5	8	4.4	4.0	0.6	1.1	0.9	44	10.5
	1	15	63	1.0	6.9	0.2	10.2	1.6	0.7	0.1	10	0.7	4.3	0.2	1.2	0.8	51	19.3
	2	1	63	0.8	7.0	0.3	10.4	1.3	0.8	0.2	10	1.1	3.8	0.4	1.5	0.6	53	9.1
	2	12	65	3.3	6.9	0.4	10.6	2.2	0.8	0.2	10	1.4	4.4	0.1	1.4	0.3	91	39.1
1990	1	1	41	1.7	6.8	0.1	6.3	0.5	0.8	0.4	14	3.4	2.9	1.4	0.4	0.3	121	24.3
	1	16	41	1.0	6.7	0.2	6.1	0.6	0.7	0.4	11	2.2	3.2	1.8	0.4	0.3	128	38.7
1991	1	1	38	0.8	6.7	0.1	10.4	7.8	0.9	0.3	13	0.8	2.1	0.3	0.8	0.5	210	31.1
	1	14	38	1.0	6.6	0.2	6.9	0.3	0.9	0.2	16	3.9	1.9	0.1	0.8	0.5	190	45.0
1992	1	1	35	1.2	6.6	0.2	5.8	1.0	0.9	0.5	12	3.4	2.5	0.9	0.6	0.3	157	9.3
	1	24	35	0.5	6.3	0.1	4.9	1.0	0.8	0.6	11	1.5	2.5	1.2	0.6	0.3	162	56.9
1993	1	1	37	1.0	6.6	0.1	7.5	2.7	0.5	0.1	7	7.5	2.2	0.4	1.3	1.1	104	34.9
	1	25	39	4.0	6.4	0.4	7.8	2.1	0.5	0.2	10	10.7	2.6	0.9	0.8	0.1	134	52.0
1994	1	1	39	6.5	6.6	0.2	6.2	2.0	1.1	0.8	5	3.2	2.2	0.9	0.6	0.2	141	44.0
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	26	36	0.9	6.3	0.3	6.5	2.5	0.7	0.3	6	4.7	2.2	0.5	0.6	0.2	197	87.7
1995	1	1	60	5.6	6.6	0.2	9.8	1.0	2.0	0.8	11	2.6	3.7	1.4	1.3	0.4	85	45.6
	1	17	60	5.4	6.5	0.2	10.0	1.3	2.3	1.2	9	2.0	3.4	0.5	1.6	0.5	101	33.0
	2	1	58	4.9	6.6	0.2	9.7	1.1	1.9	0.9	11	4.3	3.2	0.3	1.1	0.3	87	55.9
	2	11	58	4.3	6.5	0.2	9.6	1.1	2.0	0.8	10	5.5	3.5	0.4	1.3	0.3	101	53.9
1996	1	1	56	1.5	6.7	0.2	10.5	0.7	1.4	1.0	10	2.5	3.2	0.5	1.3	0.2	54	25.9
	1	18	57	2.7	6.6	0.1	11.2	1.9	1.5	0.7	9	0.5	3.1	0.5	1.1	0.3	72	33.2
	2	1	56	1.4	6.7	0.1	10.7	1.0	1.2	0.6	9	1.3	3.1	0.5	1.1	0.3	54	25.7
	2	11	57	1.1	6.7	0.1	10.7	1.0	1.5	0.6	11	2.6	2.9	0.5	1.5	0.3	89	43.4

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Year	Station	Depth (m)	Sp. conductivity (µmhos cm)	SD	pH (Units)	SD	Alkalinity (mg/L)	SD	Turbidity (NTU)	SD	Color (Pt units)	SD	Calcium (mg/L)	SD	Magnesium (mg/L)	SD	Iron (µg/L)	SD
1997	1	1	53	0.6	7.1	0.2	12.1	1.6	1.1	0.1	9	1.9	3.1	0.4	1.1	0.3	28	16.6
	1	18	58	6.7	6.8	0.2	13.9	3.5	1.7	0.4	10	0.8	2.9	0.5	1.7	1.1	68	37.7
	2	1	53	0.8	7.1	0.1	11.7	0.5	1.0	0.2	11	3.8	3.0	0.3	1.0	0.3	34	17.3
	2	13	53	0.5	7.0	0.1	11.9	0.3	1.3	0.5	10	3.0	2.9	0.3	1.0	0.3	44	25.8
1998	1	1	49	0.6	7.0	0.1	12.6	1.3	1.7	1.2	18	10.7	3.2	0.5	0.8	0.2	26	15.0
	1	18	48	ND	7.0	ND	11.8	ND	2.0	ND	11	ND	3.3	ND	1.0	ND	48	ND
1999	1	1	58	0.0	6.8	0.2	11.1	0.6	1.6	1.0	11	1.7	3.3	0.3	1.4	0.1	82	43.8
2000	1	1	ND	ND	7.1	0.2	8.7	2.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2001	1	1	ND	ND	7.2	0.4	10.1	2.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2002	1	1	ND	ND	7.2	0.5	10.1	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2003	1	1	ND	ND	6.9	0.1	9.8	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2004	1	1	ND	ND	6.9	0.1	11.4	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1	18	ND	ND	6.8	0.1	10.9	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2005	1	1	ND	ND	6.8	0.1	10.9	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2006	1	1	ND	ND	6.8	0.1	11.3	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2007	1	1	ND	ND	6.8	0.1	10.9	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2008	1	1	ND	ND	6.7	0.2	11.4	1.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2009	1	1	ND	ND	7.0	0.4	11.7	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2010	1	1	ND	ND	7.2	0.1	9.5	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2011	1	1	ND	ND	7.4	0.1	11.3	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2012	1	1	ND	ND	7.5	0.2	11.1	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2013	1	1	ND	ND	7.4	0.1	11.9	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2014	1	1	ND	ND	7.5	0.1	11.4	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pre-fertilization 1987–1989		1	55	3.0	6.8	0.3	10.5	1.3	1.3	1.2	10	2.6	4.0	0.3	1.2	0.5	57	18.1
Fertilization 1990–2000		1	49	2.1	6.8	0.2	9.5	1.7	1.2	0.6	11	3.6	2.9	0.6	1.0	0.3	91	30.0
All years 1987–2013		1	50	2.3	6.9	0.2	10.2	1.4	1.3	0.8	10.4	3.3	3.2	0.6	1.0	0.4	81.4	26.7
Post-fertilization 2001–2013		1	ND	ND	7.1	0.2	10.9	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5-year 2010–2014		1	ND	ND	7.4	0.1	11.0	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: NTU=Nephelometric Turbidity Scale. PT units=Platinum-Cobalt Scale.

Appendix A10.–Summary of seasonal mean nutrient and algal pigment concentrations by station and depth for Afognak Lake, 1987–2014.

Year	Station	Depth (m)	Total phosphorus (µg/L)	SD	Total filterable-P (µg/L)	SD	Filterable reactive-P (µg/L)	SD	Total kjeldahl nitrogen (µg/L)	SD	Ammonia (µg/L)	SD	Nitrate + nitrite (µg/L)	SD	Reactive silicon (µg/L)	SD	Organic carbon (µg/L)	SD	Chlorophyll *a* (µg/L)	SD	Phaeophytin *a* (µg/L)	SD
1987	1	1	8.8	3.6	3.1	1.5	1.6	0.3	130	5.6	4.8	2.6	134.7	57.8	3255	719.8	144	30.3	0.64	0.21	0.54	0.19
	1	17	6.7	1.0	2.8	0.6	1.4	0.2	116	14.5	12.8	11.7	147.7	51.6	3313	706.9	102	25.5	0.32	0.21	0.41	0.02
1988	1	1	8.1	2.2	4.7	1.9	2.7	0.6	140	18.9	4.2	2.0	60.4	36.0	2509	344.9	247	52.3	1.64	1.02	0.74	0.17
	1	15	7.8	1.2	4.1	0.8	2.6	0.1	124	10.6	7.1	6.3	66.9	32.9	2528	200.4	179	26.6	2.13	3.17	0.99	0.83
	2	1	8.0	2.8	5.7	4.4	3.1	0.8	128	17.6	3.5	1.9	60.2	31.3	2602	134.1	183	44.0	1.58	1.22	0.72	0.33
	2	10	7.9	2.3	3.5	1.6	2.3	0.1	133	9.6	8.0	5.7	53.8	13.2	2499	107.6	300	176.1	2.76	3.50	1.02	0.32
1989	1	1	8.3	2.8	4.2	0.6	2.4	0.4	139	17.8	2.6	3.4	67.2	47.0	2714	197.7	ND	ND	0.92	0.39	0.54	0.17
	1	15	6.5	0.7	3.9	0.5	2.5	0.2	134	11.1	9.2	10.8	76.8	32.3	2803	150.6	ND	ND	0.65	0.34	0.51	0.26
	2	1	7.1	1.6	4.2	0.7	2.8	0.5	126	10.0	3.0	4.1	69.9	45.6	2752	209.4	ND	ND	0.75	0.18	0.41	0.18
	2	12	8.8	4.5	4.8	2.1	2.5	0.3	131	30.4	13.1	16.0	76.9	40.9	2813	161.1	ND	ND	0.67	0.20	0.51	0.22
1990	1	1	4.5	1.5	2.9	4.2	3.7	1.7	128	16.5	8.0	3.0	40.3	29.1	3250	247.5	145	13.0	0.34	0.19	0.17	0.03
	1	16	5.1	2.3	1.3	1.3	2.8	1.1	118	22.7	9.7	4.2	65.0	29.1	3390	154.5	144	30.6	0.21	0.03	0.28	0.07
1991	1	1	5.0	2.8	3.2	0.6	2.3	0.4	151	22.6	11.5	1.8	56.8	21.3	2865	108.6	ND	ND	0.31	0.21	0.27	0.07
	1	14	4.6	1.5	6.0	3.5	4.5	3.2	138	12.3	13.6	5.0	69.7	23.2	2966	156.3	ND	ND	0.22	0.14	0.22	0.08
1992	1	1	3.8	0.5	4.1	2.5	3.1	2.4	135	13.9	3.3	1.7	61.7	26.1	3163	158.9	199	64.1	0.44	0.29	0.28	0.13
	1	24	3.9	1.7	4.0	3.2	2.6	1.7	127	12.8	9.6	4.1	92.8	23.1	3182	198.0	163	52.9	0.31	0.25	0.28	0.12
1993	1	1	4.5	0.8	3.7	1.3	2.8	0.5	148	18.5	5.0	2.2	49.1	30.4	3132	220.6	147	53.3	1.01	0.31	0.36	0.03
	1	25	4.9	1.3	8.5	11.7	6.8	9.9	136	17.3	19.4	10.1	98.4	31.7	3380	244.0	121	47.5	0.52	0.21	0.45	0.14
1994	1	1	5.7	0.7	4.5	3.3	3.6	2.3	160	23.8	3.2	1.7	39.8	21.4	2843	122.4	114	33.0	0.56	0.26	0.28	0.08
	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.56	0.34	0.34	0.10
	1	26	5.3	1.1	4.8	3.9	4.2	3.2	160	17.7	15.2	9.7	74.3	23.8	3177	285.5	128	52.1	0.36	0.21	0.27	0.09
1995	1	1	8.7	2.7	3.0	1.5	2.0	1.1	168	21.6	9.5	14.1	65.9	22.1	1873	735.0	ND	ND	3.92	2.44	1.13	0.62
	1	17	8.1	2.0	1.9	1.1	1.1	0.4	187	47.1	34.7	44.3	45.1	35.0	2046	618.4	ND	ND	3.13	1.75	1.10	0.54
	2	1	7.4	2.1	2.1	1.2	1.7	1.0	169	31.0	9.4	14.0	54.4	33.2	1942	753.9	ND	ND	4.20	2.90	1.05	0.65
	2	11	7.2	1.7	2.2	2.0	1.6	1.1	157	26.0	16.4	17.4	51.9	34.1	2143	805.6	ND	ND	3.27	2.18	1.05	0.62
1996	1	1	9.2	2.6	3.4	0.7	2.8	0.3	161	34.0	17.5	13.9	39.6	29.2	2465	297.2	225	80.3	2.39	1.16	0.82	0.38
	1	18	8.2	2.7	2.4	0.7	2.2	0.3	161	56.5	36.3	37.6	50.9	27.8	2663	176.1	190	73.1	1.40	0.56	0.81	0.37
	2	1	8.8	2.6	2.7	0.8	2.2	0.4	160	37.3	8.2	14.6	40.7	25.9	2466	275.0	226	52.5	1.77	0.50	0.85	0.36
	2	11	8.4	2.8	3.4	1.6	2.9	1.3	147	41.3	28.7	24.5	49.7	25.9	2630	220.7	169	55.7	1.07	0.29	0.77	0.31
1997	1	1	7.3	1.9	2.7	1.0	2.6	0.9	155	33.9	14.0	14.2	21.9	23.9	2347	354.4	273	63.8	2.56	1.42	1.51	0.66
	1	18	7.2	1.5	2.6	0.5	2.3	0.4	194	68.6	63.6	53.3	55.3	14.5	2995	503.5	197	28.8	1.12	0.50	1.08	0.38
	2	1	6.9	1.7	3.6	1.8	3.1	1.5	156	37.8	13.3	15.8	16.9	21.8	2435	351.3	252	62.8	1.68	1.25	1.19	0.83
	2	13	6.5	1.4	2.8	1.9	2.3	0.8	148	38.7	20.9	12.4	29.6	20.1	2584	433.5	156	50.6	1.33	1.17	1.06	0.76

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Year	Station	Depth (m)	Total phosphorus (µg/L)	SD	Total filterable-P (µg/L)	SD	Filterable reactive-P (µg/L)	SD	Total kjeldahl nitrogen (µg/L)	SD	Ammonia (µg/L)	SD	Nitrate + nitrite (µg/L)	SD	Reactive silicon (µg/L)	SD	Organic carbon (µg/L)	SD	Chlorophyll *a* (µg/L)	SD	Phaeophytin *a* (µg/L)	SD
1998	1	1	9.0	1.7	3.3	0.8	1.9	0.0	193	7.7	21.2	13.9	38.1	15.9	2387	73.0	152	118.8	0.10	0.04	0.04	0.02
	1	18	7.5	ND	3.7	ND	1.9	ND	182	ND	24.5	ND	62.6	ND	2311	ND	36	ND	0.09	ND	0.03	ND
1999	1	1	17.7	18.3	8.6	10.2	6.8	10.0	247	147.2	35.7	42.6	123.9	35.2	2390	431.5	261	122.2	2.94	3.19	0.56	0.35
2000	1	1	9.5	4.3	3.1	1.6	1.8	1.6	57	36.6	19.4	12.5	71.5	36.1	ND	ND	ND	ND	2.43	1.46	1.10	0.80
2001	1	1	7.8	5.1	6.4	5.2	8.2	6.7	115	22.2	4.6	3.6	37.9	32.5	ND	ND	ND	ND	2.37	0.53	0.30	0.20
2002	1	1	6.4	2.3	4.5	3.1	1.5	0.9	131	15.4	4.9	2.5	26.7	18.8	ND	ND	ND	ND	1.36	0.14	0.30	0.20
2003	1	1	6.5	3.0	2.2	0.8	2.1	0.8	ND	ND	5.7	1.8	54.4	26.9	ND	ND	ND	ND	1.20	0.20	0.50	0.40
2004	1	1	6.2	3.5	4.3	3.2	2.0	0.7	169	103.8	8.5	2.8	60.7	31.5	2764	342.8	ND	ND	1.15	0.18	0.28	0.08
	1	18	5.9	2.3	6.2	8.3	3.5	3.5	ND	ND	19.0	13.2	79.8	28.4	2914	277.1	ND	ND	0.70	0.35	0.19	0.11
2005	1	1	11.4	4.4	7.6	3.6	3.6	3.1	161	45.6	4.4	2.0	40.5	34.8	2701	243.7	ND	ND	1.60	0.68	0.24	0.11
2006	1	1	7.2	4.3	2.2	1.6	2.3	1.1	97	59.6	7.1	1.7	28.0	30.8	ND	ND	ND	ND	1.92	0.32	0.50	0.09
2007	1	1	3.6	0.4	1.1	0.3	1.1	0.6	115	32.4	5.6	0.7	55.5	39.5	ND	ND	ND	ND	1.47	0.43	0.21	0.08
2008	1	1	3.8	1.1	2.3	1.5	1.6	0.9	113	28.6	5.9	0.6	65.0	42.3	ND	ND	ND	ND	1.22	0.66	0.58	0.37
2009	1	1	4.8	1.1	1.3	0.3	1.8	1.0	131	29.7	4.2	0.8	38.8	40.0	ND	ND	ND	ND	1.92	0.64	0.63	0.33
2010	1	1	4.4	0.8	2.5	0.4	1.7	0.3	19	15.7	4.3	0.8	22.5	32.1	2363	682.2	ND	ND	1.12	0.16	0.63	0.25
2011	1	1	5.8	0.6	2.5	0.4	4.7	2.0	209	21.3	17.7	6.9	41.7	27.2	2440	254.8	ND	ND	1.19	0.62	0.62	0.23
2012	1	1	3.8	0.2	1.7	0.2	0.8	0.3	299	59.3	5.8	3.6	33.5	36.0	2806	235.5	ND	ND	1.74	0.59	0.12	0.06
2013	1	1	4.3	0.6	1.9	0.3	1.5	0.7	375	55.6	13.4	7.2	20.7	21.3	2801	238.3	ND	ND	1.31	0.51	0.38	0.16
2014	1	1	3.8	0.6	1.2	0.4	1.2	0.7	524	381.6	6.0	6.1	13.5	18.4	2312	509.8	ND	ND	1.68	0.50	0.34	0.30
Averages:																						
Pre-fertilization yrs. 1987–1989		1	8.0	2.6	4.4	1.8	2.5	0.5	133	14.0	3.6	2.8	78.5	43.5	2766	321.2	191	42.2	1.10	0.61	0.59	0.21
Fertilization yrs. 1990–2000		1	7.7	3.1	3.6	2.2	2.9	1.7	156	34.5	12.8	11.8	51.5	26.5	2581	317.6	199	66.4	1.76	1.12	0.69	0.36
All years 1987–2014		1	6.7	2.5	3.4	1.8	2.6	1.4	161	43.1	8.7	6.5	48.6	30.0	2522	317.0	183.3	56.5	1.51	0.73	0.53	0.26
Post-fertilization yrs. 2001–2014		1	5.3	1.9	2.8	1.4	2.3	1.3	175	62.2	6.5	2.7	36.0	28.8	2273	313.4	ND	ND	1.42	0.41	0.38	0.19
5-year 2010–2014		1	4.4	0.6	2.0	0.3	2.0	0.8	285	106.7	9.4	4.9	26.4	27.0	2544	384.1	ND	ND	1.41	0.48	0.42	0.20

Appendix A11.–Mean zooplankton density, biomass, and size by species for station 1, Afognak Lake, 1987–2014.

Station		*Epischura*			*Diaptomus*			*Cyclops*			*Bosmina*			*Daphnia*			*Holopedium*			Totals	
1 Year	No. samples	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)	Size (mm)	Density (no/m^2)	Biomass (mg/m^2)
1987	4	28,835	100	0.91	173	1	1.01	4,127	6	0.65	138,370	134	0.33	3,218	4	0.54	2,574	6	0.52	177,297	251
1988	4	22,360	77	0.91	0	0	-	3,185	5	0.69	106,462	104	0.33	962	2	0.71	1,228	3	0.53	134,197	191
1989	5	16,322	71	0.99	0	0	-	3,663	5	0.66	69,638	59	0.31	1,778	3	0.64	1,347	3	0.48	92,748	141
1990	7	15,378	60	0.95	7	0	0.90	9,987	16	0.68	155,051	134	0.31	3,392	5	0.61	4,944	9	0.47	188,759	224
1991	6	21,278	102	1.02	265	1	0.79	6,606	12	0.74	208,574	193	0.32	4,089	9	0.72	4,025	8	0.50	244,837	325
1992	7	23,468	104	0.99	485	1	0.88	4,807	8	0.68	106,832	108	0.33	5,513	13	0.74	3,306	6	0.45	144,411	240
1993	7	33,893	127	0.94	76	0	0.83	5,960	11	0.72	240,817	247	0.34	7,689	14	0.66	3,715	8	0.50	292,150	407
1994	8	23,713	66	0.85	1,844	7	0.98	10,231	17	0.69	257,749	256	0.33	9,621	18	0.66	7,271	13	0.48	310,429	377
1995	7	16,758	84	1.04	5,596	16	0.87	24,932	39	0.68	212,768	197	0.32	13,740	22	0.62	1,410	2	0.46	275,204	360
1996	5	42,112	223	1.06	191	0	0.49	11,614	19	0.69	350,806	378	0.34	16,072	44	0.78	2,909	5	0.47	423,704	670
1997	6	14,367	69	1.02	5,520	11	0.75	24,567	41	0.69	81,591	66	0.30	11,720	17	0.58	915	1	0.43	138,679	205
1998	4	15,672	62	0.96	1,088	5	1.05	2,070	3	0.67	169,971	144	0.31	10,881	14	0.56	5,441	8	0.42	205,123	236
1999	4	18,737	78	0.97	5,945	24	0.97	6,688	12	0.71	133,175	130	0.33	9,449	20	0.68	2,495	5	0.46	176,489	269
2000	5	57,643	180	0.88	8,121	44	1.09	10,743	16	0.66	114,297	126	0.35	5,042	9	0.64	1,408	2	0.46	116,722	188
2001	5	30,122	66	0.77	2,548	6	0.79	8,121	10	0.61	40,764	33	0.30	1,253	1	0.49	2,638	4	0.43	85,446	120
2002	4	8,174	21	0.82	1,009	3	0.92	6,380	7	0.56	38,256	36	0.32	2,935	3	0.51	557	1	0.41	57,311	71
2003	4	39,743	73	0.73	3,782	7	0.74	3,185	4	0.62	102,110	85	0.30	1,393	2	0.60	1,194	2	0.48	151,407	173
2004	5	23,206	37	0.69	510	1	0.86	6,374	8	0.62	58,598	52	0.31	11,472	16	0.58	2,771	5	0.48	102,931	119
2005	5	21,369	59	0.84	1,592	4	0.83	8,238	10	0.60	82,409	65	0.30	4,979	7	0.57	2,027	3	0.43	120,614	148
2006	5	29,565	92	0.88	3,450	10	0.85	9,915	20	0.76	76,518	61	0.30	8,408	11	0.56	6,348	11	0.46	134,204	205
2007	5	10,913	24	0.78	2,930	9	0.88	7,718	13	0.70	74,257	66	0.31	3,386	5	0.58	1,730	3	0.47	100,934	120
2008	5	16,561	45	0.84	823	2	0.83	2,670	3	0.61	66,762	55	0.30	4,231	7	0.62	3,079	6	0.49	94,126	119
2009	5	13,402	42	0.88	0	0		1,409	2	0.60	31,539	24	0.29	2,866	4	0.54	1,208	2	0.45	50,424	73
2010	5	14,841	48	0.89	212	1	0.82	987	1	0.59	64,830	49	0.29	1,327	2	0.53	1,624	3	0.49	83,821	104
2011	5	16,423	50	0.86	1,911	2	0.61	4,501	6	0.61	43,068	31	0.28	446	1	0.57	2,972	6	0.49	69,321	95
2012	5	23,928	82	0.91	425	1	0.81	3,854	6	0.66	56,359	45	0.30	4,310	7	0.64	1,104	3	0.53	89,980	143
2013	5	12,155	37	0.87	106	0	0.91	4,979	7	0.61	50,334	35	0.28	6,502	8	0.54	2,856	5	0.43	76,932	91
2014	5	23,617	90	0.92	531	2	0.98	2,123	4	0.73	88,429	69	0.29	8,493	10	0.53	2,017	5	0.52	125,210	180
Averages:																					
Pre-fertilization yrs. 1987–1989		22,506	83	0.94	58	0	1.01	3,658	5	0.67	104,823	99	0.32	1,986	3	0.63	1,716	4	0.51	134,747	194
Fertilization yrs. 1990–2000		25,729	105	0.97	2,649	10	0.87	10,746	18	0.69	184,694	180	0.33	8,837	17	0.66	3,440	6	0.46	228,773	318
All yrs. 1987–2013		22,627	77	0.90	1,800	6	0.85	7,315	11	0.66	115,997	108	0.31	5,803	10	0.61	2,707	5	0.47	153,267	210
Post-fertilization yrs. 2001–2013		20,031	52	0.83	1,484	4	0.82	5,256	7	0.63	60,446	49	0.30	4,116	6	0.56	2,316	4	0.46	93,650	122
5-year 2010–2014		18,193	61	0.89	637	1	0.83	3,289	5	0.64	60,604	46	0.29	4,216	5	0.56	2,115	4	0.49	89,053	123

Appendix A12.–Mean zooplankton density, biomass, and size by species for station 2, Afognak Lake, 1988–2014.

Station		*Epischura*			*Diaptomus*			*Cyclops*			*Bosmina*			*Daphnia*			*Holopedium*			Total	
2	No.	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass	Size	Density	Biomass
Year	Samples	(no/m^2)	(mg/m^2)	(mm)	(no/m^2)	(mg/m^2)	(mm)	(no/m^2)	(mg/m^2)	(mm)	(no/m^2)	(mg/m^2)	(mm)	(no/m^2)	(mg/m^2)	(mm)	(no/m^2)	(mg/m^2)	(mm)	(no/m^2)	(mg/m^2)
1988	4	10,656	45	0.98	40	0	1.44	809	1	0.70	108,838	110	0.33	1,405	3	0.65	942	3	0.55	122,690	162
1989	5	10,306	35	0.90	0	0	-	1,261	2	0.66	48,235	40	0.30	420	1	0.63	553	1	0.46	60,775	79
1990	7	12,610	48	0.94	0	0	-	3,460	5	0.66	128,277	108	0.31	2,350	4	0.64	4,026	7	0.47	150,723	172
1991	6	19,285	80	0.97	1,274	4	0.89	4,277	8	0.74	154,341	132	0.31	3,347	6	0.65	5,083	10	0.49	187,607	240
1992	7	8,948	34	0.94	144	1	1.00	1,436	2	0.67	82,879	84	0.33	2,521	5	0.70	1,579	3	0.45	97,507	129
1993	7	19,033	70	0.93	773	1	0.69	3,882	5	0.62	175,106	157	0.32	2,570	5	0.67	3,988	7	0.47	205,352	245
1994	8	11,006	40	0.93	783	3	0.91	2,736	4	0.65	125,352	116	0.32	4,321	7	0.64	2,468	4	0.46	146,666	174
1995	7	12,193	44	0.92	1,168	4	0.94	9,054	11	0.61	111,525	98	0.31	8,902	12	0.58	1,152	1	0.4	143,994	170
1996	5	20,892	99	1.02	255	2	1.17	2,930	6	0.77	219,747	239	0.35	4,331	11	0.76	1,571	2	0.46	249,726	359
1997	6	13,677	57	0.97	3,468	7	0.75	3,822	5	0.64	86,060	63	0.29	9,652	13	0.56	924	1	0.41	117,601	146
1998	ND																				
1999	ND																				
2000	ND																				
2001	ND																				
2002	ND																				
2003	ND																				
2004	5	27,192	44	0.70	32	0	0.95	5,125	8	0.66	34,843	27	0.29	2,187	4	0.62	1,624	3	0.44	71,003	84
2005	5	22,282	60	0.83	0	0	-	2,850	4	0.63	49,992	37	0.29	815	2	0.73	900	1	0.38	76,839	104
2006	5	9,408	14	0.68	510	1	0.78	3,083	5	0.70	44,282	31	0.28	3,571	5	0.59	1,274	2	0.43	62,128	59
2007	5	16,269	63	0.95	1,141	4	0.93	6,693	12	0.71	57,065	49	0.31	934	1	0.55	2,049	4	0.50	84,151	133
2008	5	20,786	51	0.81	1,592	8	1.04	2,484	3	0.59	49,260	38	0.29	786	2	0.67	1,314	2	0.44	76,222	103
2009	5	5,149	11	0.77	106	0	0.70	1,645	2	0.64	16,189	10	0.27	1,380	2	0.51	902	2	0.46	25,371	27
2010	5	4,273	6	0.67	0	0	-	504	1	0.55	25,653	16	0.26	191	0	0.65	1,205	2	0.41	31,826	24
2011	5	12,452	29	0.78	2,017	3	0.71	3,312	6	0.70	55,032	36	0.27	1,077	2	0.59	1,592	3	0.47	75,482	78
2012	5	8,386	29	0.97	1,699	4	0.81	1,964	2	0.61	37,155	28	0.29	743	1	0.57	955	2	0.49	50,902	67
2013	5	8,567	15	0.71	0	0	-	1,741	3	0.69	41,465	33	0.29	1,932	3	0.58	1,200	2	0.48	54,905	56
2014	5	9,502	41	0.91	372	1	0.96	1,274	3	0.84	59,395	41	0.27	4,459	5	0.49	318	1	0.49	75,320	92
Averages:																					
Pre-fertilization yrs.1988–1989		10,481	40	0.94	20	0	1.44	1,035	2	0.68	78,537	75	0.32	913	2	0.64	748	2	0.51	91,733	121
Fertilization yrs. 1990–2000		14,705	59	0.95	983	3	0.91	3,950	6	0.67	135,411	125	0.32	4,749	8	0.65	2,599	4	0.45	162,397	204
All yrs. 1988–2013		13,668	44	0.87	750	2	0.91	3,153	5	0.66	82,565	73	0.30	2,672	4	0.63	1,765	3	0.46	104,573	131
Post-fertilization yrs. 2001–2013		13,476	32	0.79	710	2	0.85	2,940	4	0.65	41,094	30	0.28	1,362	2	0.61	1,302	2	0.45	60,883	73
5-year 2010–2014		8,636	24	0.81	818	2	0.83	1,759	3	0.68	43,740	31	0.28	1,680	2	0.58	1,054	2	0.47	57,687	63

Appendix A13.–Sockeye salmon escapement and adult returns by age for Afognak Lake, 1982–2014.

Brood		Age class returns																Total	
Year	Escapement	0.1	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	4.1	2.4	3.3	return	R/S
1982	123,055	2	0	17	112	5,504	112	0	13,845	762	0	0	371	0	0	0	0	20,726	0.17
1983	40,049	0	0	337	0	9,828	297	0	10,013	4,627	0	0	1,707	0	0	35	0	26,844	0.67
1984	94,463	0	0	1,588	54	24,634	1,307	0	47,110	22,360	0	339	24,078	0	0	0	0	121,471	1.29
1985	53,872	36	96	272	0	10,583	2,902	0	26,542	10,030	0	0	6,568	0	0	65	0	57,094	1.06
1986	48,333	0	0	8,022	35	54,737	717	0	108,494	4,958	0	428	10,370	0	0	0	0	187,760	3.88
1987	26,474	0	0	773	0	20,889	313	0	25,139	3,198	99	0	9,772	177	0	0	0	60,359	2.28
1988	39,012	0	0	472	0	18,628	8,360	0	23,626	9,607	57	77	9,686	80	0	0	0	70,593	1.81
1989	88,825	0	0	17,807	0	8,321	13,427	0	35,677	10,450	157	253	13,374	0	0	397	0	99,863	1.12
1990	90,666	0	0	12,902	0	30,978	4,194	0	96,927	18,526	0	397	56,869	175	0	0	199	221,167	2.44
1991	88,557	0	280	9,681	277	37,463	1,440	0	96,284	4,507	0	48	22,573	0	0	0	0	172,552	1.95
1992	77,260	0	0	3,925	175	20,223	4,698	0	70,857	3,087	0	365	5,377	0	0	0	0	108,706	1.41
1993	71,460	0	0	35,159	0	40,046	10,200	0	47,921	10,364	222	330	8,915	646	0	0	680	154,484	2.16
1994	80,570	0	0	7,863	0	7,842	6,959	74	12,841	57,821	74	0	52,384	2,531	0	0	205	148,593	1.84
1995	100,131	0	0	18,569	0	52,527	718	0	11,888	4,523	0	0	11,396	0	75	0	0	99,696	1.00
1996	101,718	0	0	1,463	0	1,888	264	0	6,789	925	4,213	0	996	6,818	0	0	3,992	27,348	0.27
1997	132,050	0	30	1,571	0	3,202	1,787	0	6,775	5,147	171	0	8,408	787	0	186	875	28,938	0.22
1998	66,869	0	0	399	0	207	666	0	238	7,296	0	3	4,225	0	0	0	0	13,033	0.19
1999	95,361	0	0	20	0	6,409	67	0	2,996	291	0	0	293	0	0	0	0	10,076	0.11
2000	54,064	0	0	1,173	0	6,971	26	0	18,560	495	0	36	2,199	0	0	0	0	29,460	0.54
2001	24,271	0	0	177	164	2,258	142	0	5,176	608	0	8	1,202	0	0	0	0	9,735	0.40
2002	19,520	0	0	716	20	14,769	0	0	11,665	435	0	1	196	0	0	0	0	27,803	1.42
2003	27,766	0	0	580	0	7,074	71	0	14,358	1,054	0	1	890	0	0	0	0	24,028	0.87
2004	15,181	0	0	1,105	0	11,631	90	0	15,538	710	0	64	140	0	0	0	0	29,278	1.93
2005	21,577	0	0	1,238	0	13,151	911	0	51,698	328	0	200	9,530	0	0	0	0	77,056	3.57
2006	22,933	0	0	1,492	0	10,108	127	0	18,494	5,727	0	54	4,876	0	0	0	0	40,878	1.78
2007	21,070	0	0	1,691	0	26,090	2,119	0	26,626	6,553	0	20	5,549	0	0	0	0	68,648	3.26
2008	26,874	0	0	2,753	0	7,379	367	0	31,931	2,570	0		4,873	0					
2009	31,358	0	0	1,094	0	9,801	0		16,230	5,203	0								
2010	52,255	0	0	92		8,365	245												
2011	49,193	0	0	1,373															
2012	41,553	0																	
2013	42,153																		
2014	36,345																		
Averages:																			
Pre fertilization yrs.																			
1982–1989	64,260	5	12	3,661	25	19,141	3,429	0	36,306	8,249	39	137	9,491	32	0	62	0	80,589	1.54
Fertilization yrs.																			
1990–2000	87,155	0	28	8,430	41	18,887	2,820	7	33,825	10,271	425	107	15,785	996	7	17	541	92,187	1.10
All yrs. 1982–2007	64,161	2	16	5,093	33	16,795	2,392	3	31,178	7,513	200	104	10,656	449	3	27	238	74,702	1.38
Post fertilization																			
yrs. 2002–2007	21,875	0	0	885	31	9,832	224	0	19,488	1,477	0	55	2,806	0	0	0	0	34,796	2.14

Note: Escapement reflects egg take removals. Years after 2007 not fully recruited.

Appendix A14.–Number and percentage of sockeye salmon escapement into Afognak Lake, by year, and ocean age, 2000–2014.

	Ocean Age								
Year	1	%	2	%	3	%	4	%	Total Fish
2000	1,361	2.5	6,404	11.8	46,300	85.6	0	0.0	54,064
2001	5,443	22.4	3,490	14.4	15,338	63.2	0	0.0	24,271
2002	804	4.1	11,423	58.5	7,293	37.4	0	0.0	19,520
2003	1,344	4.8	14,410	51.9	12,012	43.3	0	0.0	27,766
2004	194	1.3	7,206	47.5	7,618	50.2	163	1.1	15,181
2005	833	3.9	2,664	12.3	18,080	83.8	0	0.0	21,577
2006	550	2.4	15,234	66.4	7,109	31.0	41	0.2	22,933
2007	1,143	5.4	7,280	34.5	12,640	60.0	8	0.0	21,070
2008	1,252	4.7	12,181	45.3	13,442	50.0	0	0	26,874
2009	2,263	7.2	13,242	42.2	15,853	50.6	0	0	31,358
2010	1,480	2.8	8,501	16.3	42,222	80.8	52	0.1	52,255
2011	3,693	7.5	24,112	49.0	21,237	43.2	152	0.3	49,193
2012	1,294	3.1	12,331	29.7	27,881	67.1	48	0.1	41,553
2013	78	0.2	10,438	24.8	31,621	75.0	17	0.0	42,154
2014	1,618	4.5	13,623	37.5	21,104	58.1	0	0.0	36,345
Average (2000–2013)	1,552	5.2	10,637	36.1	19,903	58.6	34	0.1	32,126
Average (2010–2014)	1,632	3.6	13,801	31.4	28,813	64.8	54	0.1	44,300

Appendix A15.–Relative yearly phytoplankton and mean biovolume in Afognak Lake, by phylum, 2010–2014.

		Phylum							
		Chlorophyta (green algae)	Chrysophyta (golden-brown algae)	Bacillariophyta (diatoms)	Cryptophyta (crytomonads)	Pyrrhophyta (dinoflagellate)	Haptophyta	Cyanobacteria (blue-green algae)	
Date	Station								Total
2010	1	130,541	2,265,299	4,740,446	2,682,616	18,313,380	29,984	210,536	28,372,803
		0.5%	8.0%	16.7%	9.5%	64.5%	0.1%	0.7%	
2011	1	17,375	267,446	228,802	40,010	42,107	8,767	50,280	654,787
		2.7%	40.8%	34.9%	6.1%	6.4%	1.3%	7.7%	
2012	1	52,430	0	728,394	134,374	209,872	0	18,027	1,143,096
		4.6%	-	63.7%	11.8%	18.4%	-	1.6%	
2013	1	12,639,969	85,184,272	117,045,785	13,003,103	6,260,603	0	2,393,609	236,527,341
		5.3%	36.0%	49.5%	5.5%	2.6%	-	1.0%	
2014	1	24,359,942	19,690,417	173,028,927	21,991,389	82,351,757	0	3,364,528	324,786,960
		7.5%	6.1%	53.3%	6.8%	25.4%	-	1.0%	
Mean		6,200,043	17,901,239	49,295,392	6,308,582	17,862,953	6,459	1,006,163	98,580,831
Mean %		3.4%	18.2%	36.4%	6.6%	19.6%	0.5%	2.0%	

Appendix A16.–Estimated sockeye salmon outmigration and survivals by age and year, 2003–2014.

	Outgoing									Incoming					
	Sockeye salmon smolt outmigration									Age composition based on escapement					
	Estimate by age and year					Freshwater-age-1 survival				Ocean survival					
Year	Age-1	%	Age-2	%	Total	Eggs produced [a]	Smolt estimate	Egg to smolt survival		Age-1	% Survival	Age-2	% Survival	Total	% Survival
2003	373,513	66.1%	191,279	33.9%	564,793	33,639,606	373,513	1.1%		22,013	5.9	2,015	1.1	24,028	4.3
2004	387,584	90.1%	42,420	9.9%	430,004	27,740,800	387,584	1.4%		28,338	7.3	940	2.2	29,278	6.8
2005	521,025	93.0%	39,205	7.0%	560,230	28,668,395	521,025	1.8%		66,287	12.7	10,768	27.5	77,055	13.8
2006	146,527	71.4%	58,626	28.6%	205,153	16,031,136	146,527	0.9%		30,149	20.6	10,729	18.3	40,878	19.9
2007	237,383	86.2%	38,067	13.8%	275,450	23,680,758	237,383	1.0%		54,424	22.9	13,355	35.1	67,779	24.6
2008	92,018	46.7%	104,923	53.3%	196,941	23,815,921	92,018	0.4%		37,072	40.3	14,204	13.5	51,276	26.0
2009	427,141	86.6%	64,560	13.1%	492,998	27,337,272	427,141	1.6%		47,471	11.1				
2010	237,716	76.9%	71,415	23.1%	309,130	28,545,025	237,716	0.8%							
2011	250,741	76.0%	79,207	24.0%	329,948	40,445,235	250,741	0.6%							
2012	99,541	77.6%	28,321	22.4%	127,861	80,933,164	99,541	0.1%							
2013	249,107	81.7%	55,630	18.2%	305,033	80,930,848	249,107	0.3%							
2014	135,410	62.0%	82,830	38.0%	218,239	61,952,614	135,410	0.2%							
Mean (2003–2013)	274,754	77.5%	70,332	22.5%	345,231			0.9%	Mean (2003–2009)	40,822	17.3				
Mean (2010–2014)	194,503	74.8%	63,480	25.1%	258,042			0.5%	Mean (2003–2008)			8,669	16.3	48,382	15.9

[a] Based on Adjusted escapement (less brood stock removed), proportion of female spawners, and fecundity.